Developing an Analytical Framework for Quantifying Greenhouse Gas Emission Reductions from Forest Fuel Treatment Projects in Placer County, California

Prepared For:

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Executive Summary

The western U.S. has millions of acres of overstocked forestlands at risk of large, uncharacteristically severe or catastrophic wildfire owing to a variety of factors, including anthropogenic changes from nearly a century of timber harvest, grazing, and particularly fire suppression. Various methods for fuel treatment intended to modify or reduce fire severity include mastication or removal of sub-merchantable timber and understory biomass, pre-commercial and commercial timber harvest, and prescribed fire. Mechanisms for cost recovery of fuel treatments are not well established, and return on investment comes primarily in the form of avoided wildfire. While the benefits of fuel treatments in reducing effects of wildfire are clear and well-documented in the scientific literature, the absolute probability of wildfire impacting fuel treatments or nearby areas within their effective lifespan are difficult to account for with certainty and are variable across the landscape. As market-based approaches to global climate change are being considered and implemented, one important emerging strategy for changing the economics of fuels treatments is to carbon emission offset credits for activities that reduce greenhouse gas emissions beyond what is required by existing permits or rules. Carbon emission offsets can theoretically be generated by projects that reduce potential emissions from wildfire, as by reducing effects of wildfire for a given portion of land. Development of carbon emission offsets as an effective tool for forest and fire mangers requires an integrated approach that considers wildfire probabilities and expected emissions, as well as net expected carbon sequestration or loss over time.

To assist the United States Forest Service (USFS) and Placer County in establishing a rigorous approach for evaluating the potential for carbon emission offsets from fuel treatment projects, Spatial Informatics Group, in conjunction with the University of California, has developed a framework that integrates scientifically based models for predicting changes in fire behavior and related emissions, both with and without hazardous fuel treatments. Major elements of the methodology include characterizing firesheds and their elements, estimating forest stock and growth, quantifying the life cycle of forest carbon wood products, assessing the risk of fire to the fireshed, determining direct wildfire emissions, quantifying the effect of treatments on wildfire emissions outside their boundaries, and calculating net GHG benefits or liabilities resulting from treatments.

Using the carbon emission offset framework in a case study of the Last Chance area, we demonstrated that:

- Fuel treatments had significant impacts on potential wildfire emissions, both direct (emissions from within the treatments themselves) and indirect (in the form of reduced expected fire size).
- The effects of treatment on fire size deteriorated over time. To a certain point (i.e. the effective life span of the treatments), these effects had an important impact on avoided emissions, at least for the "thin from below" treatments (Alt-SNAMP and USFS-Standard).
- GHG storage and offsets from wood products and biomass energy production created significant GHG benefits, but even in the most intensive management scenario (Private-Harvest) were never more than 50% of the net GHG deficit created by biomass removal in fuel treatments. The remaining deficit had to be offset by avoided wildfire emissions in order to create a net GHG benefit at any time step.
- Avoided wildfire emissions (and thus net GHG benefits or liabilities) were highly sensitive to the probability of wildfire and the form of its application (e.g. constant or variable).
- Net GHG benefits were only realized when the probability of wildfire was high (15 year expected return interval), and only for the thin-from-below treatments (Alt-SNAMP and USFS-Standard).

- The “Private Harvest” scenario based on commercial harvest of trees up to 30 inches in diameter with a minimum retained basal area of 75 ft^2/acre (Table 3) realized no net GHG benefit at any point in the study period, using any expected fire frequency or risk model. Though there was a significant and long lasting effect on fire behavior, avoided emissions were never enough to compensate for removal of large amounts of stored carbon during treatment.
- Balancing the goals of carbon sequestration and forest resiliency to fire may require optimizing treatments to maximize fire behavior reduction, retention of large fire resistant trees, longevity of treatment effectiveness, timing of long-term follow up treatments, and wood product and biomass offsets.
- This study helps provide insights into landscape scale GHG benefits associated with managing forests for fire hazard and risk reduction.
- While GHG emissions are a current area of focus within forest management, interpretation of findings from this study should be considered within the framework of findings from previously published studies that have quantified additional ecosystem co-benefits of reducing stand density, actively restoring forest structure, and reintroducing fire as an ecosystem process at a landscape scale.

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Introduction

The western U.S. has millions of acres of overstocked forestlands at risk of large, uncharacteristically severe or catastrophic wildfire owing to a variety of factors, including anthropogenic changes from nearly a century of timber harvest, grazing, and particularly fire suppression (Miller et al. 2009). Modification of fuel structures and reduction of unnaturally high fuel loads in order to alter fire patterns and behavior are a primary component of planning efforts such as the National Cohesive Wildland Fire Management Strategy (Wildland Fire Leadership Council 2011) and the Sierra Nevada Forest Plan Amendment (USDA Forest Service 2001), and are likely to continue or increase into the future in response to climate change and the resulting changes in fire and fuels. Various methods for fuel modification, collectively termed “fuel treatments,” include mastication or removal of sub-merchantable timber and understory biomass, pre-commercial and commercial timber harvest, and prescribed fire. Cost per unit area for fuel treatments varies by treatment method and vegetation type (Hartsough et al. 2008), but complete treatment of vast areas of at-risk wild lands is neither financially feasible nor logistically realistic, or even desirable under certain land management objectives. Mechanisms for cost recovery of fuel treatments are not well established, and return on investment comes primarily in the form of avoided wildfire, though the absolute probability of wildfire impacting fuel treatments or nearby areas within their effective lifespan can be relatively low and variable across the landscape (Hurteau et al. 2009, Ager et al. 2010a, Syphard et al. 2011).

Various strategies are emerging to deal with fuel treatment cost. Given limited resources and the inability to treat every at-risk acre, treatments can be strategically arranged on the landscape in order to increase their effectiveness in protecting communities within the wildland urban interface (WUI) and natural resources, changing expected fire effects, and aiding fire suppression efforts, which can reduce overall fire sizes (Ager et al. 2007a, Ager et al. 2007b, Moghaddas et al. 2010). Additionally, forest woody biomass removed in fuel treatments can be used for higher value purposes and products, such as electricity and heat, transportation fuels (e.g., advanced biofuels), chemicals, and physical products used directly in many activities and industries (e.g. bioplastics, ash, glass aggregates). The federal interagency Biomass Research and Development Technical Advisory Committee, created to support the Biomass R&D act of 2000, has set goals of increasing the market share of biopower to 7.0% (3.8 quadrillion Btu) by 2030 (Biomass Research Development Technical Advisory Committee 2006). However, while the market for woody biomass may be expanding, it still faces significant hurdles, such as limited access to funding, distance between forest treatment and biomass utilization facilities, public perception of the effects of biomass removal, and scientific documentation to support the sustainability of these activities (Evans 2008).

As market-based approaches to global climate change are being considered and implemented, one important emerging strategy for changing the economics of fuels treatments is to sell carbon emission offsets , tradable certificates or permits representing the right to emit a designated amount of carbon dioxide or other greenhouse gasses (GHGs). These offsets are generated when projects or actions reduce GHG emissions beyond what is required by permits and rules, and can be traded, leased, banked for future use, or sold to other entities that need to provide emission offsets (Sedjo and Marland 2003). In the case of fuel treatments, carbon emission offsets can theoretically be generated by projects that reduce potential emissions from wildfire, as by modifying the probability of extreme fire behavior for a given portion of land. In 2006, the California legislature enacted Assembly Bill 32: The Global Warming Solutions Act (AB32), setting emissions goals for 2020 and directing the Air Resources Board to develop reduction measures to meet targets (State of California 2006). Forest management (including fuel treatments) is one area that has been targeted for project based offset development. The EPA and those agencies implementing AB32 require that carbon emission offsets be quantifiable, real, permanent, enforceable, verifiable, and surplus.

Development of carbon emission offsets as an effective tool for forest and fire mangers therefore requires an integrated approach that considers wildfire probabilities and expected emissions, as well as net expected carbon sequestration or loss over time. Western forests have the potential to sequester large amounts of carbon in the form of woody biomass, but increased forest densities and understory growth can also increase fire hazard (Stephens et al. 2009a). Fuel treatments intended to reduce the risk of severe wildfire and associated emissions by definition remove live and dead woody biomass available for burning, thereby reducing stored carbon. Fuel treatment operations themselves can also result in direct and delayed atmospheric carbon emissions, as with biomass transportation and prescribed broadcast or pile burning. Several recent studies have investigated the seemingly competing values of carbon sequestration and fuel treatment, examining whether and to what extent reduced carbon sequestration from treatment is mitigated by avoided emissions (Hurteau and North 2009, North et al. 2009, Stephens et al. 2009b, Ager et al. 2010a, Reinhardt and Holsinger 2010).

The United States Forest Service (USFS) is the largest manager of forested land in the Sierra Nevada Mountains of California, and is aggressively pursuing means to reduce the costs of fuels treatments, demonstrate their multiple benefits, and enable markets for carbon sequestration and other ecosystem services based on such treatments. USFS Region Five (R5) and Pacific Southwest Research Station (PSW) have coordinated on a number of fronts over the past several years to develop strategies to manage the substantial flow of wood waste from fuels reduction treatments. The PSW Sierra Nevada Ecosystems Research Initiative (formerly known as the Sierra Nevada Research Center – RWU-4202) investigates landscape level impacts of ecological disturbance and change through multiple disciplines, including wildlife ecology, fire sciences, economics and policy and institutional analysis.

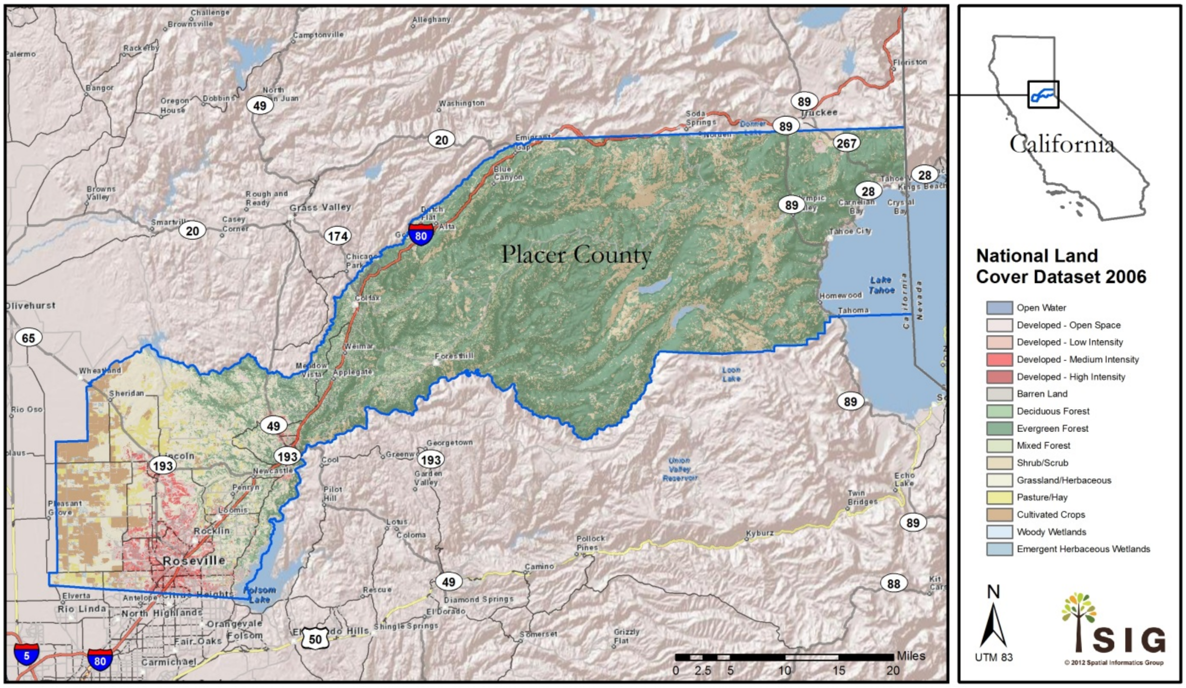


Figure 1: National Land Cover Dataset 2006 for Placer County.

Placer County, located in Northern California east of Sacramento, encompasses a large portion of the Sierra Nevada from its western foothills east to their crest near Lake Tahoe, including portions of both the Tahoe and El Dorado National Forests. 55% of Placer County land cover can be classified as deciduous, mixed, or evergreen forest (Figure 1) (Fry et al. 2011). 64% of Placer County have been classified as "High" or "Very High" fire hazard by the California Department of Forestry and Fire Protection (Figure 2) (California Department of Forestry and Fire Protection 2007). Currently, the USFS, landowners, and municipalities of Placer County are pursuing fuels reduction and mitigation strategies to reduce wildfire risk. Placer County is actively working with public and private forest management organizations on a number of forest fuels reduction projects to reduce the potential for catastrophic wildfire events. These projects include selective thinning and removal of trees and brush to return forest ecosystems to more natural stocking levels, resulting in a more fire-resilient forest.

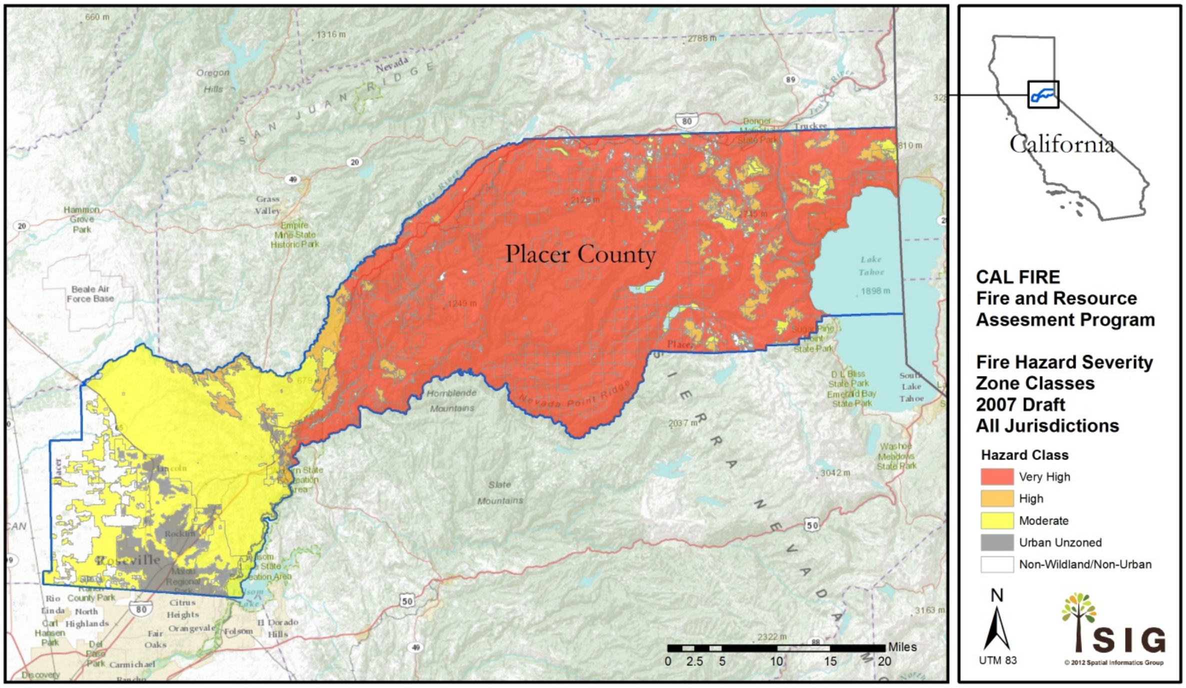


Figure 2: CalFire FRAP Fire Hazard Severity Zones for Placer County, California.

Placer County is exploring the possibility of supporting these local forest management projects by offering greenhouse gas (GHG) emission offsets to project developers that require GHG emissions mitigation consistent with the California Environmental Quality Act (CEQA). In order for Placer County to offer emissions reduction offsets, it is necessary to develop a methodology that relies on scientifically based models for estimating carbon benefits that will occur in response to hazardous fuels reduction treatments.

Three types of carbon benefits can be realized from management of established forests:

1. GHG emissions from wildfires can be reduced by decreasing the probability, extent, and severity of wildfires and the corresponding loss in forest carbon stocks;

2. The GHG emissions from fossil fuel energy can be replaced by using excess biomass from forest management projects for energy production; and

3. Management and thinning of forests can stimulate growth, resulting in more rapid uptake of atmospheric carbon.

4. Sequestering woody biomass removals in wood products.

To assist the USFS and Placer County in establishing a rigorous approach for carbon emission offsets, Spatial Informatics Group, in conjunction with the University of California, has developed a methodology that integrates scientifically based models for predicting changes in fire behavior and related emissions, both with and without hazardous fuel treatments. The goal is to produce an integrated framework of process-based models that will provide localized estimates of potential relative emissions reductions. To perform such an assessment, forest composition, structure, and fuels must be characterized as inputs to forest growth, fire behavior and emissions models, and the size and shape of the area for fire hazard assessment (i.e. the fireshed) must be identified. Estimates of potential behavior and emissions must be made for treated and untreated landscapes over time. The potential for emissions reductions to actually be realized in different locations and vegetation types must also be quantified (i.e. baseline absolute probabilities, from long-term observed relationships between fire and environmental variables that influence regional fire occurrence rates). This report outlines the results of this approach, as applied to the Last Chance study area in Placer County.

Solutions generated from this Placer County applied project can be replicated elsewhere, both within and outside the National Forest System, to assist forest managers in offsetting fuels treatments costs with revenue generated by offsets programs. This project is consistent with the USFS Chief's emphasis on research to mitigate the effects of climate change on forest ecosystems. Additionally, this project fits within PSW RWU-4202 Problem Areas 1 and 5. Problem area 1 addresses research intended to improve Forest Function and Health. This research may make fuels reductions projects more economically viable in the near future. This will result in improvements in long-term forest health and air quality. Problem Area 5, Sub-Problem 2 of RWU-4202, focuses on modeling the relationships and trade-offs among resource values, and interactions with market forces, to support policy development. Consistent with Sub-Problem 2 is the need for the continuing development of predictive models that can be evaluated and used to quantify and document potential greenhouse gas emissions reductions from forest fuels treatments activities. This research will enable RWU-4202 to develop methods that can be used by the Placer County Air Pollution Control District (PCAPCD) to quantify potential greenhouse gas reductions from forest management activities, particularly on the Western Slope of the Sierra Nevada.

Background

Fuel treatments are now a generally accepted means of dealing with the millions acres of overstocked forests in the western US and the resulting forest fire hazard. The various methods of fuel treatment have different effects on ecosystem elements, and can be used to achieve a variety of resource management goals beyond fire protection. Efficacy and effects of fuel treatments in real world situations (e.g., wildfire) has been demonstrated in several instances (Graham 2003, Finney et al. 2005, Moghaddas and Craggs 2007, Ritchie et al. 2007), but the majority of scientific evidence for their use comes from modeling efforts (Stephens and Moghaddas 2005, Stephens et al. 2009a, Vaillant et al. 2009, Ager et al. 2010b, Moghaddas et al. 2010, Collins et al. 2011). Overall, there is clear consensus in the published literature that fuel treatments, specifically those that incorporate thinning from below and treat surface fuels with prescribed fire, reduce potential fire severity under a range of moderate to extreme weather conditions. Though now recognized as an important tool for fire protection and ecosystem process restoration, detailed strategies for application of the various techniques in different vegetation types at a landscape scales are still under study (Collins et al. 2010, Collins et al. 2011).

Concerns over global climate change seemingly place fuel treatments, (which by their nature remove stored carbon in the form of woody biomass from forests) at odds with long-term carbon sequestration in terrestrial vegetation as a means of climate change mitigation. Though wildfires also combust biomass and can be a significant source of atmospheric carbon emissions in the near-term (Randerson et al. 2006, Ager et al. 2010a), they may also act as mechanisms for long-term carbon sequestration in some systems (Hurteau and Brooks 2011). Several recent studies have investigated whether the GHG emissions avoided through fuel treatment can offset immediate losses of stored carbon and carbon emitted during operations, and even possibly result in net positive carbon storage over longer time periods (Mitchell et al. 2009, North et al. 2009, Stephens et al. 2009b, Ager et al. 2010a, Cathcart et al. 2010, Hurteau and North 2010, Reinhardt and Holsinger 2010, Campbell et al. 2011).

While carbon accounting itself is a conceptually straightforward method of tallying the sources and sinks of carbon, quantifying actual carbon stocks and flows (whether historical, current, or future) for ecological systems at a landscape scale is complex because of the spatial and temporal trends, interactions, and feedbacks of ecosystem processes. Wildfires, which are crucial disturbance processes in many of the world's ecosystems, are a prime example of that complexity. Fires occur as a function of a "fire regime triangle" of factors that regulate long-term fire activity: ignition sources, vegetation type, and climatic conditions during the fire season. Some portions of the landscape are in more fire-prone environments than others, which mean that some fuels treatments are more likely to achieve their emissions reduction benefits than others. This study, along with other current research by SIG and others, uses current scientific understanding of ecosystem processes to create a framework for evaluating and quantifying this potential. We use an area in the North-Central Sierra Nevada Mountains as a case study for creating the framework.

Objectives

The goal of this study is to provide methods of analysis to support a protocol for Placer County to subsequently develop a carbon offset procedure to recognize the greenhouse gas benefits from a program which links project-level fuels reduction efforts to changes in landscape-level fire and GHG emissions outcomes. The specific objectives are to:

1. Develop a framework and methodology that the Placer County Air Pollution Control District's (PCAPCD) GHG offset program will be able that can be used to quantify and document GHG (and criteria pollutant) emissions reductions from both forest fuels treatments and biomass energy utilization activities, particularly on the Western Slope of the Sierra Nevada in Placer County.
2. Enable the PCAPCD ability to identify the risk of catastrophic wildfire in Placer County and take action to reduce those risks through cost-effective fuels reduction activities.
3. Develop multiple management scenarios to be tested within the framework to highlight the variability of potential results.

Study Area

The Last Chance study area, located within the Tahoe National forest in the north-central Sierra Nevada mountains (Figure 3). The study site has a Mediterranean climate, receiving precipitation averaging 1,182 mm/year over the period of record 1990–2008 (Hell Hole Remote Automated Weather Station), predominantly in the form of snow. Vegetation within Last Chance is typical of west-slope Sierra Nevada forests, composed primarily of mixed conifer forest dominated by white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr. var. *lowiana* (Gord.) Lemmon), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var.

menziesii), and incense-cedar (*Calocedrus decurrens* (Torr.) Florin) with sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*Pinus ponderosa* var. *ponderosa* Dougl.). California black oak (*Quercus kelloggii* Newb.) appears as a co-dominant at variable densities throughout, with stands of montane chaparral interspersed throughout the area as well. Since Euro-American settlement, the Last Chance Study area has been influenced by a range of activities, including railroad logging in the early 20th century (Beesley 1996), changing climates (Miller et al. 2007), intensive forest management through the 20th century (Beesley 1996), and fire exclusion (McKelvey et al. 1996), similar to much of the west-slope of the Sierra Nevada. Studies of similar forest types in nearby areas suggest pre-historic fire return intervals of 5-15 years (Stephens and Collins 2004).

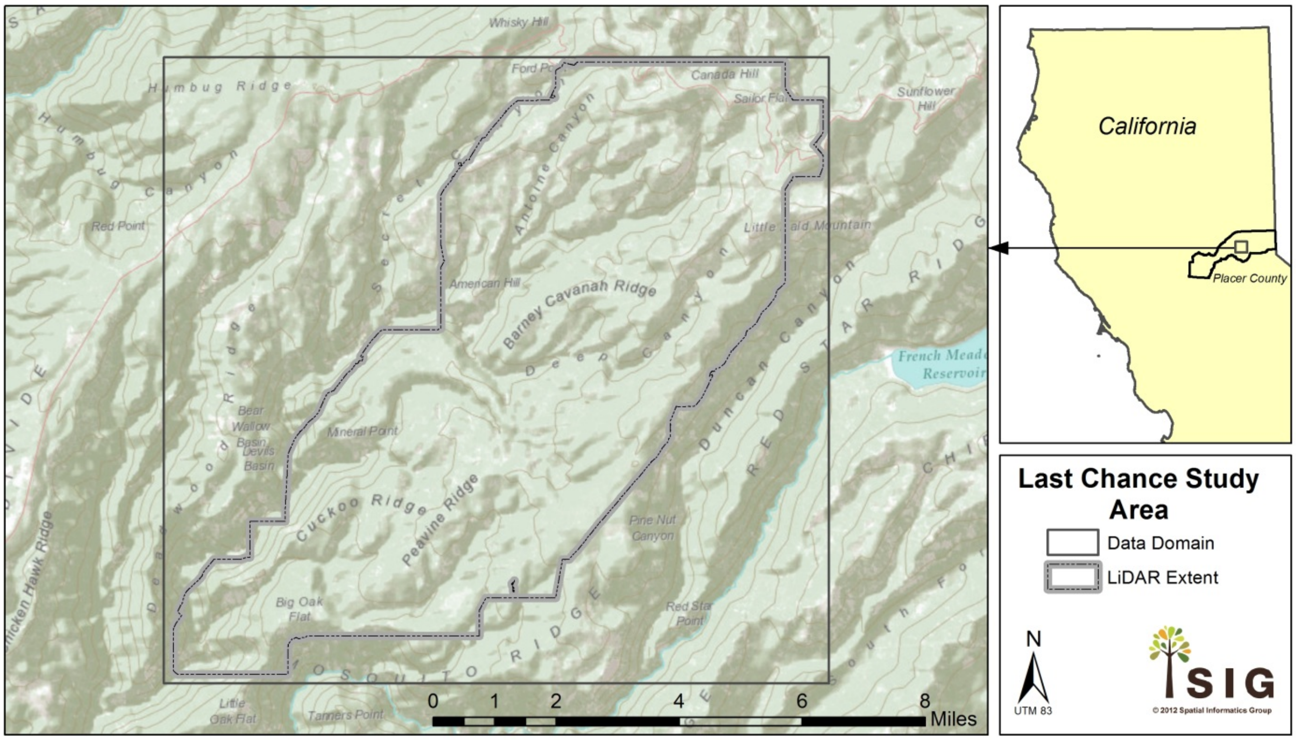


Figure 3: Last Chance study area

Methodology

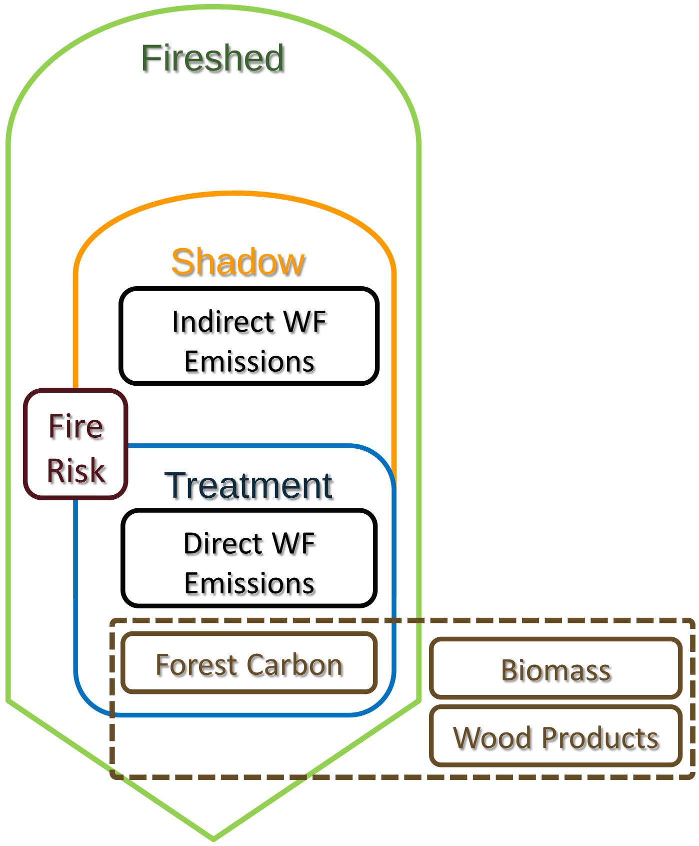
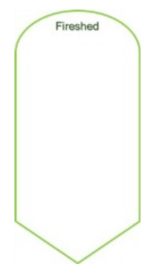


Figure 4: Conceptual Framework

A conceptual framework for estimating potential wildfire emission reduction credits for a particular fireshed is illustrated in Figure 4. Major elements of the methodology include characterizing firesheds and their elements, estimating forest stock and growth, quantifying the life cycle of forest carbon wood products, assessing the risk of fire to the fireshed, determining direct wildfire emissions, quantifying the effect of treatments on wildfire emissions outside their boundaries, and calculating net GHG benefits or liabilities resulting from treatments. Treatments are fuels reduction projects such as thinning or prescribed fire. Treatment shadows are areas outside treatments that are affected by treatments in terms of fire hazard or emissions. GHG emissions estimates (pre and post treatment) are a function of total stored carbon, CO2 contained per mass of carbon, size of fireshed, emission coefficient, and wildfire risk. The framework was designed to be consistent with standard carbon market accounting principles used for determining credits. The net benefit of treatments on avoided wildfire emissions is quantified by integrating the impacts of wildfire treatments on multiple carbon pools compared to a business-as-usual (BAU) baseline. This framework incorporates treatment effects within defined forest carbon pools, the net impact of treatments on those carbon pools, the impact of direct carbon emissions from wildfire amortized by the risk of wildfire, the impact of indirect carbon emissions from wildfire amortized by the risk of wildfire, and a localized life cycle assessment that includes biomass utilization. The emissions associated with the recovery and transportation of biomass and wood products is not incorporated in this analysis. This framework incorporates an assessment of fossil fuel displacement, assuming that biomass energy production is not necessarily carbon neutral.

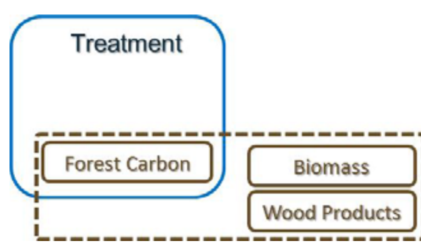
Conceptual Framework Elements

The net avoided emissions resulting from treatment activities are determined by summing up the emissions associated with the individual framework elements. The results are presented as atmospheric emissions and sinks. Forest emissions, e.g. stored carbon removed from the forest, are compared to avoided wildfire emissions, along with avoided emissions from wood products and bioenergy. The framework includes the emissions from the recovery, transportation, processing, or fossil fuel substitution of biomass or merchantable wood products. Some of these elements are thought to be limited given the magnitude of the other pools, while others are assumed to be neutral based on policy decisions. Below is a brief description of framework elements. Quantification of these elements is described in more detail later in the report.



Fireshed: The fireshed is the basic unit of measure used in this accounting framework. It is an area of land of a scale that allows the ecologically relevant integration of wildfire risk, wildfire hazard, and forest carbon accounting. Firesheds are delineated, vegetation within firesheds is quantified and classified, and the results from each of the proceeding elements are geo-summarized at the fireshed scale into common units for use in the analytical framework.

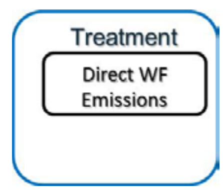
Forest Carbon: Forest carbon storage is the sequestration of carbon in biomass (plant or tree trunks, branches, foliage, or roots) or soils through photosynthesis and growth over time. Forest carbon emissions are losses of stored carbon from the forest. Forest emissions may be due to wildfire, or removal of woody biomass in the form of fuel treatments, and may be offset by utilization (e.g. wood products or energy production) or a potential reduction in wildfire emissions. The type and intensity of treatments have several effects on this framework. Treatments directly change the amount of forest carbon in the fireshed, as well as influencing post treatment growth and carbon accumulation. Treatment type also influences the amount of merchantable and non-merchantable wood that comes out of the fireshed and thus impacts the emissions associated with wood product Life Cycle Analysis (LCA). Several elements are integrated in this measure including growth, yield, and regeneration.



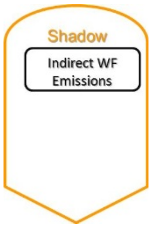
Wood Products and Energy Production Benefits: There can be a substantial amount of biomass removed from the fireshed during fuel treatments. Understanding the fate of biomass removed from the fireshed, and ultimately how much winds up as carbon sources vs. sinks is a critical component of this framework which has a significant impact on the overall results. Several assumptions are made in this assessment regarding biomass. First, it is assumed that there is a viable biomass energy industry within reach of the fireshed. It was assumed that biomass removed from the fuel treatments are sent to a mill in Lincoln California which is approximately 70 miles from the project area. The mill is the largest on the West Coast, has small and large log lumber lines, and a 30 MW biomass waste boiler producing both electricity and steam for on-site use in lumber drying kilns Second, we assume that wood products will be sent to a local mill, and that merchantable timber is going to its highest and best use. The analysis assumes that merchantable sawlogs are made into lumber products. Mill wastes are used for energy and landscaping and animal bedding products. Non-merchantable biomass is processed and transported and used for producing electricity at the sawmill boiler. Third, we assume that treatments will be implemented fully within the firesheds. 4th, the analysis assumes that price points for biomass have been relatively stable over the past 5-10 years and are assumed to be stable going forward for the analysis period. Current biomass prices are relatively low and on market demand, prices are not expected to increase significantly during the modeled period (Personal communications with Tad Mason, TSS Consultants). Finally, carbon for biomass waste processing and transport is directly included in the factors used to assess the benefits of biomass waste utilization (Springsteen et al. 2011). Several more assumptions are parameterized as part of the analysis framework and described in detail throughout the report. The emissions from wood products are determined for both merchantable and non-merchantable material removed from the fire shed. The total avoided wood product emissions are determined by summing up the avoided emissions from the non-merchantable and merchantable wood product life cycles.

Fire Risk: Fire risk is used to discount the potential wildfire emissions savings from a given fire by the probability of the fire occurring. Fire risk is assessed in several different ways for the study including estimating the present (historical) return interval that incorporates fire suppression, and the prehistoric fire return interval (prior to Euro-American settlement) through paleoecological studies and spatially explicit models of probability based on environmental variables. The framework allows for application of differing levels of fire risk and temporally stochastic models of probability to different scenarios in order to compare alternatives under different conditions.

Direct Wildfire Emissions Benefits: Direct wildfire emissions are defined as the emissions observed or expected for each unit of area on the landscape. Reductions (benefits) in direct emissions from treatment are a direct result of reduction in fuel loads and arrangements (and resultant fire behavior) within those treatment areas. Total direct emissions are summarized at the fireshed scale (per unit-area) and are independent of any effect of wildfire outside the treatments themselves. The direct emissions benefit from treatment is quantified using a dynamic baseline assessment approach, described later in this report. The analysis is conducted for the complete time period amortized by the risk of fire.

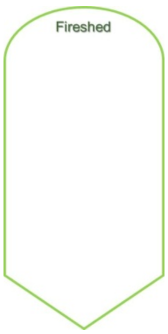


Treatment Shadow: A fuel treatment shadow refers to an area outside fuel treatments that experiences altered or reduced fire behavior as a result of the treatment. It is an area that has not been treated per se, but benefits from the treatment nonetheless. For example, treatments may reduce the ultimate size of the fire, or cause reduced fire effects in the area behind the treatment (relative to the direction of fire movement, typically the leeward side) (Finney et al. 2005). Treatment shadow effects are the changes in fire behavior or emissions associated with the treatment shadow, and are quantified in the framework as the expected change in fire size due to treatment.



Indirect Wildfire Emissions Benefits: Indirect wildfire emissions benefits are the reductions in emissions realized due to the treatment shadow effect. Indirect emissions benefits are calculated by discounting expected direct emissions by the expected change in fire size, using a dynamic baseline assessment method, described later in this report. The analysis is conducted for the complete time period amortized by the risk of fire.

Fireshed



The term "fireshed" is increasingly being used to denote a management unit used for fire planning. This is similar to the notion of natural resources being managed on a "watershed" basis, with actions in different portions of the watershed having effects on other parts within the watershed, or on the ultimate output (water resources) of the unit. Events or actions such as wildfire or fuels management activities in a fireshed can also have effects on areas greater than just the local area immediately affected. For example, forest thinning in one area may have a "shadow effect", not only altering fire behavior and emissions in the treatment unit, but in adjacent areas as well. The cumulative effects of multiple treatments in an area may therefore result in greater effects across the entire area than just the sum of the individual treatments. Firesheds may also capture areas where similar fire response strategies may be used to influence wildfire outcomes (Bahro et al., 2007). These examples demonstrate the need for a planning unit greater in size than that of wildfires, treatments, or other management activities. The following steps describe the methods used to delineate firesheds and their core components:

Step 1: Define the Fireshed Boundary

Firesheds are generally delineated based on topography, fuels and vegetation patterns, assessment of fuel treatment effectiveness, barriers to fire spread, and fire behavior expected under relatively extreme fire weather conditions. Currently the USFS is implementing and refining its Stewardship and Fireshed Assessment (SFA) process across many of its forests in California (Bahro et al., 2007). An early part of this broad planning process is to delineate firesheds, within which fire management activities can be effectively planned and fuel treatment effectiveness evaluated. Fireshed delineation within the SFA process is a collaborative process, based on elements such as stakeholder input, expert opinion, and simulation of the "problem fire" for the planning area. The problem fire is a simulated fire that is of primary concern to stakeholders for its potential impact to lives, property, forests, and watersheds (Bahro et al., 2007). It is based on exploration and examination of fire history and historical weather for an area.

The SIG methodology for delineating firesheds improves on the current, somewhat subjective methods of fireshed delineation by adding a new ecologically and statistically based approach. We integrate data for the study area on land cover, weather, topography, and fire probability into a semi-automated statistical process that divides or regionalizes the study area into firesheds. The resulting fireshed is then populated with field-based information to create the base landscape which serves as the analytical canvas for this analysis. Below is a description of the individual steps used to create this canvas.

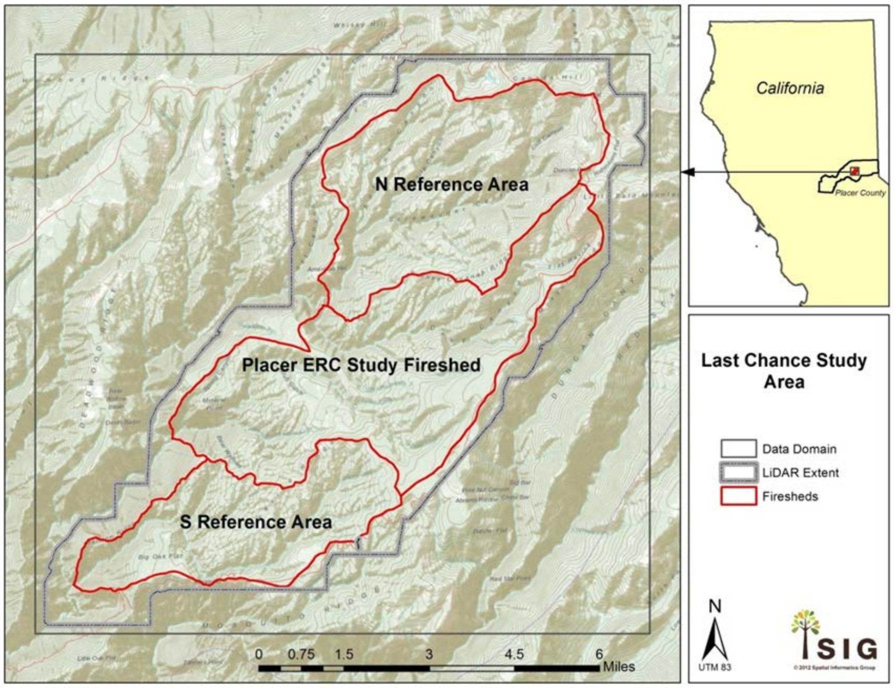


Figure 5: Firesheds in the Last Chance case study. Total area of each fireshed is as follows: Placer Carbon Emission Offset Study Fireshed = 10,604 acres, N Reference Area = 8,534 acres, S Reference Area = 5,443 acres.

Approach: The Last Chance study area is an actual landscape fuel treatment project area on the Tahoe National Forest. USFS managers have designed a fuel treatment program for this area that included delineating firesheds. Firesheds were delineated using the Stewardship Fireshed Analysis framework (Bahro et al., 2007) focusing on the "problem fire" for the area. The Sierra Nevada Adaptive Management Project further evaluated this treatment project using the same firesheds (Collins et al., 20011). We used these firesheds for this project (Figure 5), as they provided a basis for comparison to previous planning efforts.

Though not used for this study, the SIG methodology for fireshed delineation is presented here for reference as part of the proposed carbon emission offset Framework. Our methodology generally considers five main factors: the "fire behavior triangle" (fuels, weather and topography) (Pyne et al., 1996), barriers to fire spread (both natural and anthropogenic), potential fire behavior (under a "near-worst case" weather scenario), fire occurrence probability patterns, and contemporary fire history (CalFire FRAP Database, 1900-2007). The analysis is performed in a Geographic Information System, and begins by performing an analysis of barriers to fire spread within the study area. These barriers may include major roads and water courses, areas with no burnable vegetation, and agricultural areas. The study area is then divided up by this barrier layer to form "barrier units". These barrier units serve as our broadest unit of analysis, as fire would likely be contained within these large units. Each barrier unit is analyzed separately. Barrier units are subsequently divided into smaller "fire basins", based on the California Watershed Boundary Dataset (WBD) subwatershed delineations (6th level, 12-digit)(CalWater, 2010). These topography-based polygons are hydrologic units that define the aerial extent of surface water drainage to a point. They served as the smallest, most basic units of analysis, as they are generally smaller than the anticipated firesheds (~3,000 to ~40,000 acres), and are to some degree also naturally bounding units for fire.

Each fire basin is then attributed with a value for each of several environmental variables of interest. Fire basins are given values for majority vegetation type (such as from the National Land Cover Database), wind speed expected under a near-worst case scenario, and topographic roughness index (TRI). Each fire basin is also assigned values for potential fire behavior (mean flame length, mean fire line intensity, and majority crown fire activity level) as modeled in FlamMap (Finney, 2006) under near-worst case weather conditions (97.5th percentile). Finally each fire basin is assigned a value for mean annual burn probability, averaged over the entire fire basin. The result of these assignments is a multivariate dataset for each barrier unit, with each fire basin as an observation, attributed with the multiple variables mentioned above.

Within each barrier unit, fire basins are aggregated into larger units (firesheds) based on multivariate analyses of the fuels, weather, topography, fire behavior, and fire probability data assigned to each fire basin. Units which are the most similar and adjacent to one another get aggregated into larger firesheds. A minimum size for firesheds is set, based on the idea that that each fireshed should be larger than the "problem" or near-worst case scenario fire. In cases where clusters do not meet the minimum fireshed size requirement, they may be manually combined with other clusters based on adjacency, topography, and land cover type. In some instances, it may not be possible to meet the minimum size requirement due to fire barrier, political boundaries, or other constraints.

Step 2: Quantify Vegetation, Classify Land Cover, and Select Initial Fuel Models

Several general approaches exist for classifying and quantifying vegetation characteristics from remotely sensed data. Traditional "pixel-based" approaches rely on classifying the spectral information contained in imagery. "Object-based" approaches that build upon such previous techniques as image segmentation, edge detection, and feature extraction, are rapidly developing due to the recent availability of high-resolution (i.e. sub-meter) imagery (Blaschke, 2010). Pixel-based approaches to automated feature extraction only make use of the spectral information in an image and ignore most of the elements of image interpretation. These approaches have been heavily criticized because they yield maps far inferior to those derived using traditional photointerpretation (Olson 2009). In contrast, manual interpretation of remotely-sensed imagery is considered to be a more accurate means to map objects such as impervious surfaces (Kampouraki et al. 2008). Because humans are uniquely adept at extracting features, they make use of spectral (tone), geometric (shape, size) and contextual information (site, association, pattern) in an image, collectively referred to as the elements of image interpretation (EII) (Olson 1960). The major drawback to manual interpretation is that it is very time consuming and costly. However, a promising new set of techniques termed Object-Based Image Analysis (OBIA) can automate land-cover mapping. OBIA techniques make use of the EII, automating what trained human imagery analysts can accomplish. Several studies have demonstrated that OBIA techniques are superior to traditional "pixel-based" approaches for impervious surface mapping (Thomas et al. 2003, Finke et al. 2009, Miller et al. 2009), and some have even concluded that the accuracy can approach that of manual interpretation (Kampouraki et al. 2008).

Additionally, traditional image interpretation has been primarily derived from "passive" sensors, such as aerial and satellite imaging systems that rely on reflected energy. In forested areas, the ground can be obscured by tree canopies, which can dominate the reflected signal. Again, the human vision system is uniquely adept at detecting objects, such as tree canopies, that are only partially visible (Johnson and Olshausen 2005); however, active sensing technology such as Light Detection and Ranging (LiDAR), in which energy is emitted from the sensor and can be used to detect features of the forest canopy and sub-canopy that are obscured from above, can be of great assistance in approximating this human ability. Figure 6 provides an example of

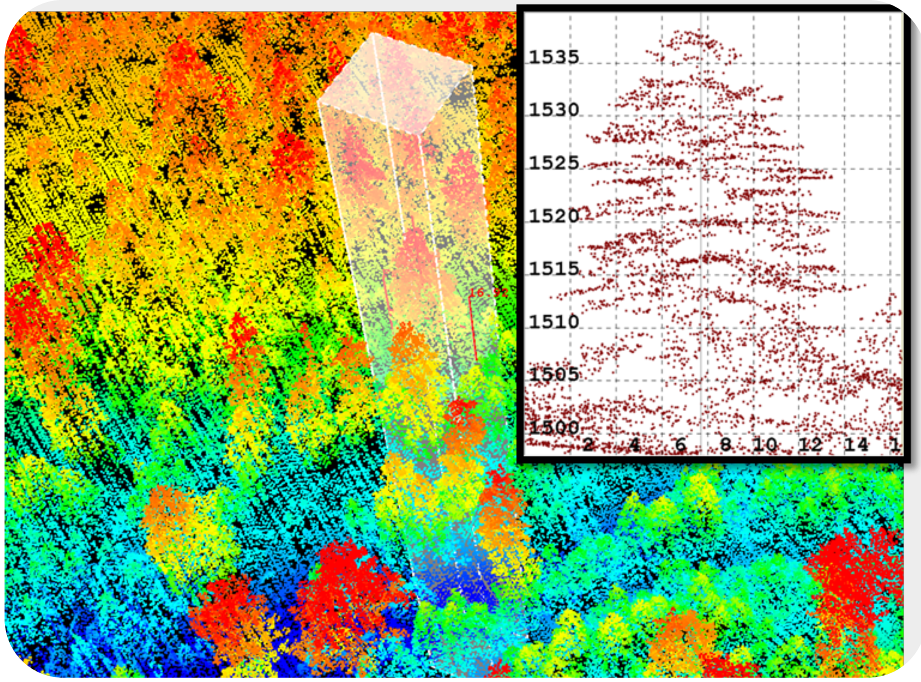


Figure 6:Interpreting forest canopy characteristics using LiDAR.

how LiDAR can augment passive-sensing technology (satellite imagery) to support vegetation characterization, by emitted energy from LiDAR penetrating the tree canopy. Several recent studies have also pointed out the advantages of using the spectral information from high-resolution imagery in combination with the structural information from the LiDAR for a data-fusion approach (Hodgson et al. 2003, Oczipka et al. 2008, Yu et al. 2009). The challenge of this approach lies in in the need for high performance computing to handle the sheer volume of data that must be processed for areas as large as the Last Chance study area or Placer County.

Fuelbed characterization and classification is one of the most critical elements of emissions estimation. A fuelbed is composed of the live and dead vegetative materials that can combust in a fire. It can include various vertical strata, including duff and litter on the forest floor, dead and downed woody material, live and dead herbs and shrubs, small trees in the under- and mid-story canopy, and live and dead trees of the upper canopy. Fuelbeds also vary horizontally (aerially) across the landscape. To account for horizontal variation, a particular study area can be spatially classified into one or more fuelbed types, each considered homogenous within itself. Fuel models are numerical descriptions for particular fuelbed types, which can be used to estimate fire behavior or smoke emissions. Fuel models were originally devised as a way to organize fuel data for input into Rothermel's (1972) mathematical fire spread model (Deeming et al., 1977). Various fuel model systems exist and are in use today, which have developed along different lines for different purposes (Table 1). Fuelbed classification for fire behavior analysis can be achieved or augmented through remote sensing techniques (LANDFIRE 2010), but is still most reliably accomplished using a combination of remotely sensed imagery, field data and expert opinion.

Table 1: Fuel model systems currently in use.

Fuel Classification System	Intended Use	Intended Scale	Compatible Models/Systems (Customize fuel models?)	Fuel elements characterized	Mapped Data
Fire Behavior Prediction System (in combination with canopy data)	Surface and crown fire behavior prediction	Site Specific	BehavePlus (Yes), FlamMap (Yes), Farsite (Yes)	Dead and down woody material up to 3" diam. Live herbs and shrubs.	Entire US (LANDFIRE), Various state, local, project-based maps (various mapping methods)
National Fire Danger Rating System	Surface fire danger prediction	Broad	NFDRS (No), FEPS (YES)	Dead and down woody material up to 8" diam. Live herbs and shrubs.	Entire US (WFAS)
Vegetation cover - based classifications (in FOFEM)	Fire effects and emissions prediction	Site Specific	FOFEM (Yes)	All dead and down woody material. Live herbs and shrubs. Litter and Duff. Canopy foliage and 0-1/4" branch wood. Rotten logs.	Entire US (LANDFIRE)
Fuel Characteristic Classification System	Fire emissions prediction	Site Specific	FEPS (Yes), FOFEM(Yes), Consume (Yes)	Trees (over-, mid-, and under-story). Class 1,2, and 3 snags. Primary and secondary shrub layers. Primary and secondary herb layers. All dead and down woody fuels (sound). Rotten woody fuels >3". Sound, rotten and pitchy stumps. Piles. Litter. Lichen. Moss. Upper and lower duff layers. Basal accumulations.	Western US (LANDFIRE)

Approach: We derived high-resolution land cover for the Last Chance area, which was in turn used to produce a forest stand map. The final land cover data set consisted of eight land cover classes. The forest stand map consisted of four stand types. The source data for the land cover classification consisted of 4-band imagery acquired through the National Agricultural Imagery Program (NAIP) (Figure 7), high-resolution Light Detection and Ranging (LiDAR) data (Figure 8), and a vector roads layer.

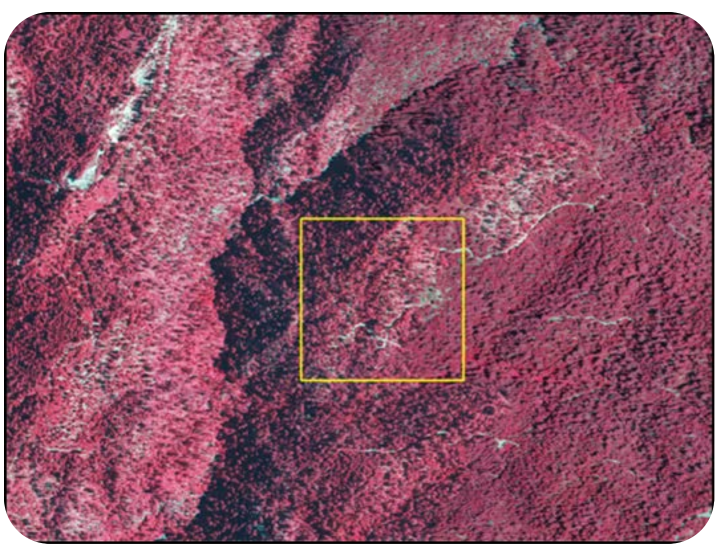


Figure 7: NAIP data for a portion of the Last Chance area displayed as a color infrared composite. The yellow square indicates the extent of The LiDAR data in the following figure.

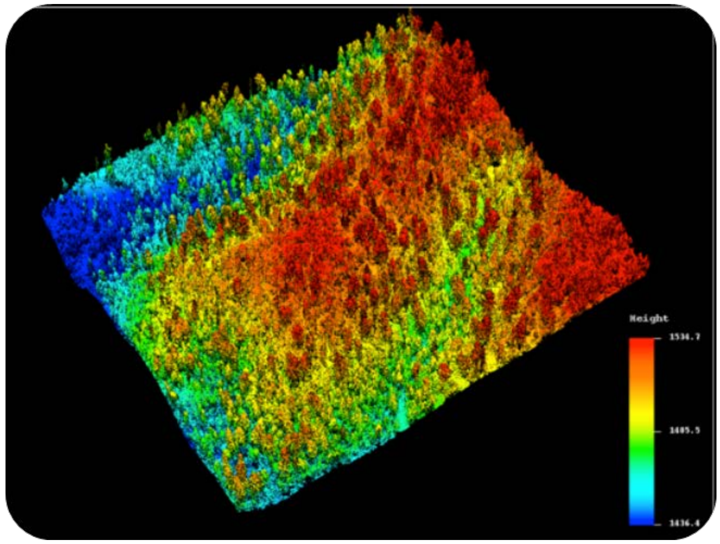


Figure 8: A portion of the LiDAR data set covering the Last Chance area

Knowledge engineering in combination with Object-Based Image Analysis (OBIA) techniques were used to derive land cover. The knowledge engineering process incorporated spectral/height, geometric, textual, and contextual information into a rule-based expert system that classified image objects created through a series of segmentation and morphological operations. A portion of the expert system developed through the knowledge engineering process is shown in Figure 9. The expert system was developed using the Cognition Network Language® (CNL) deployed using the eCognition®. The final land cover data set was over 3 billion pixels in size and contained the following classes: Bare Soil, Grass, Paved, Shrub, Tree Canopy Tall, Tree Canopy Medium, Tree Canopy Short, and Water. A sample of the final land cover layer is shown in Figure 10.

Figure 9: A portion of the expert system developed to classify land cover types.

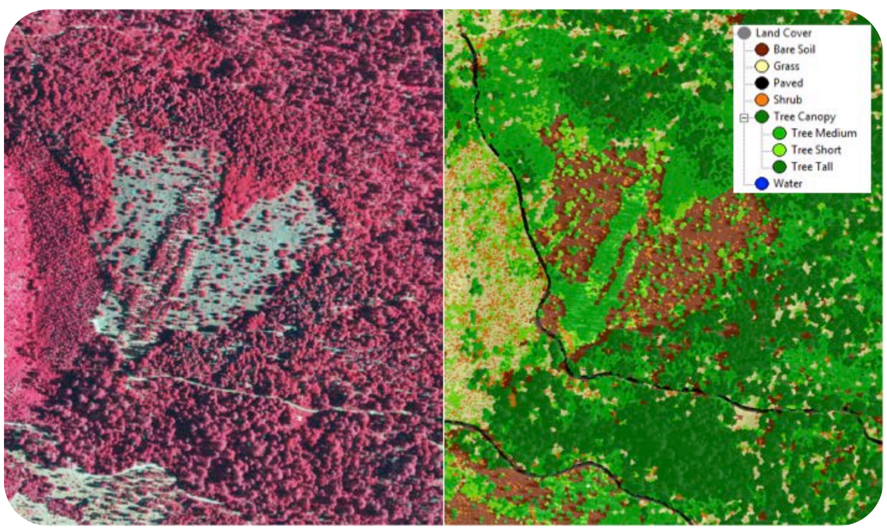


Figure 10: NAIP imagery (left) displayed next to the final land cover for a portion of the Last Chance area.

Following the development of the land cover layer a second rule-based expert system was used to first segment the forest areas into stands and then classify these stands into four broad stand types: Clear-cut (recent), Regrowth, Forested – young, and Forested – mature. For each stand, three metrics were calculated from LiDAR data: elevation, stand height, and stand density. These three metrics were also derived for each of 200 field plots within the Last Chance study area. Stand metrics were then compared to field plot metrics to assign a full suite of vegetation and fuel characteristics (Figure 11). Characteristics of the nearest field plot with the most similar metrics were used to populate "tree lists" and derive fuel characteristics for each stand for use in tree growth (FVS), fire behavior (FlamMap) and emissions (Consume) models.

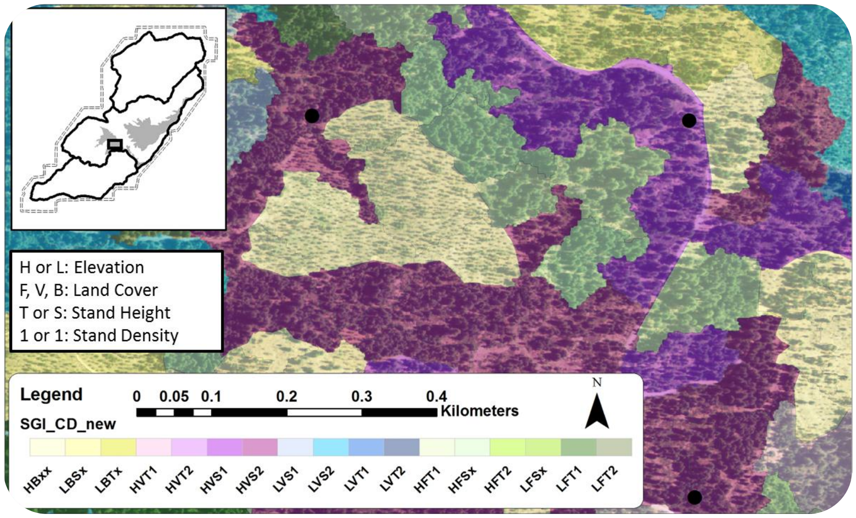
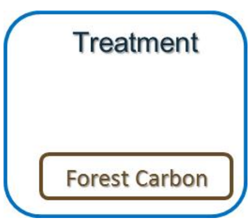


Figure 11: Stand segments classified by primary plot metrics to be used in assigning tree lists.

We used the surface fuel models of Scott and Burgan (2005) for fire behavior prediction, as these are the primary inputs into our fire behavior models (FlamMap). Fuel models for the base (pre-treatment) landscape were initially assigned using a regression tree analysis (De'ath and Fabricious,2000) in the SNAMP project, as described by Collins et al., 2011. Fuel model assignments for treated and untreated stands at each of the five-year timesteps were derived using Fire and Fuels Extension (FFE) of FVS, during our tree growth and carbon storage calculations. Fire behavior fuel models were cross-walked into FCCS fuelbed classes for emissions estimations in Consume, as described in Collins et al, 2010.

Net Forest Carbon Emission: Treatment Effects on Forest Carbon



As in much of the forested land of the Western US, fuel treatments are being applied in the Sierra Nevada in various ways. Objectives for fuel treatment generally include protecting communities, reducing wildfire size and severity, or restoring altered systems by creating conditions that may favor reference fire regime characteristics and promote forest resiliency. Fuel treatment design, techniques and methods of application vary across land ownership and management goals. In middle elevation mixed coniferous forests, such as those covering much of Placer County and the Last Chance study area, the goal is usually to reduce the chance of high severity or "catastrophic" wildfire by promoting conditions that favor low intensity surface fires over high intensity crown fires in strategic places to enhance firefighting efforts or help confine fire to certain geographic areas. Planning efforts for fuel treatments usually involve estimating potential fire behavior under near worst-case scenarios (e.g. 95th percentile weather) (Stephens et al., 2010).

On a stand level, these objectives are achieved by either reducing fuel loads (total mass of fuels available for combustion) or altering their arrangement. Usually both are done in combination. This is accomplished by reducing surface fuels on the forest floor, increasing the height to the live crown of trees (impeding transfer of fire to the canopy), reducing forest canopy density (impeding tree-to-tree spread), and retaining large fire resistant trees (Agee and Skinner, 2005). Reduction of surface fuel mass is usually accomplished through prescribed fire. Low intensity broadcast burning reduces fuels over an entire treatment area, though piling and burning of natural and activity fuels (usually after thinning or harvest) is more common. Mastication techniques, such as grinding, chipping or crushing of natural and activity fuels are often used to alter the arrangement of surface fuels to reduce risk of fire reaching the canopy. Height to live crown can be increased by removing small, suppressed, or otherwise non-merchantable trees, pruning limbs of larger trees, and removing or masticating other fire-prone vegetation such as shrubs. This can be done by hand or machine, usually in combination with overstory thinning to reduce canopy density and closure. Thinnings range in intensity from low ("thin from below"), where suppressed and intermediate trees are removed, to high ("thin from above"), where codominant and dominant trees are removed. Low thinnings over large treatment areas are generally more efficiently accomplished with machines (mechanical), rather than by hand and typically do not involve removal of enough merchantable-sized trees to be economically self.-sustaining. High thinnings can reduce canopy closure, and provide financial offset through harvesting of merchantable timber. Residual slash (non-merchantable trees, and the limbs and tops of merchantable trees) can be either left on site to be piled and burned, broadcast burned, or masticated, or it can be hauled to a landing with the merchantable material, as in the case of whole-tree yarding (a common practice today). On a larger "landscape" scale, geographic placement and spatial arrangement of fuel treatments is used strategically to alter large-scale fire spread patterns. Two methods in use today for treatment arrangement are Defensive Fuel Profile Zones (DFPZs) (Agee et al. 2000) and Strategically Placed Landscape Area Treatments (SPLATs) (Finney 2001). The following steps describe the methods used to quantify the effect of treatments on forest carbon over a 40 year period:

Step 1: Define Scenarios

A "business as usual" (BAU) scenario was defined as a reference or control, wherein no management activity would be undertaken over the 40 year study period. Based on collaborative input from an interdisciplinary group of professionals with an understanding of common silvicultural treatments in the study area, a set of three general management scenarios was developed considering ownership, management goals and constraints. These scenarios were based on 1) the Sierra Nevada Adaptive Management Project ("Alternative-SNAMP"), 2) the United States Forest Service ("USFS-Standard") management strategies, and 3) a management scenario that could be implemented on private lands ("Private-Harvest") (Figure 12). Under each management scenario, each stand within the study fireshed was assigned a general treatment type. The four treatment types were "Grow", "Thin", "Masticate" and "Underburn". For the Alternative-SNAMP and USFS-Standard management scenarios, assignment of these categories to specific stands (e.g. spatial arrangement of treatment types) was based on USFS recommendations as described in Collins et al (2010). The Private management scenario expanded upon these assignments to treat a greater proportion of the fireshed than either the Alternative-SNAMP or USFS-Standard management scenarios. A nearest neighbor assignment method was used to find stands which were similar and contiguous to those treated in the Alternative and USFS scenarios. Table 2 lists total area treated by each category under the different management scenarios.

Table 2: Scenario treatment area distribution.

Treatment Type	Management Scenario		
	Alt - SNAMP	USFS - Standard	Private - Harvest
Control / Grow (no treatment)	7,974	7,974	4,658
Mastication	259	259	
Thin	1,801	1,801	4,368
Underburn	573	573	1,582
% Treated	**25%**	**25%**	**56%**
Grand Total	**10,607**	**10,607**	**10,607**

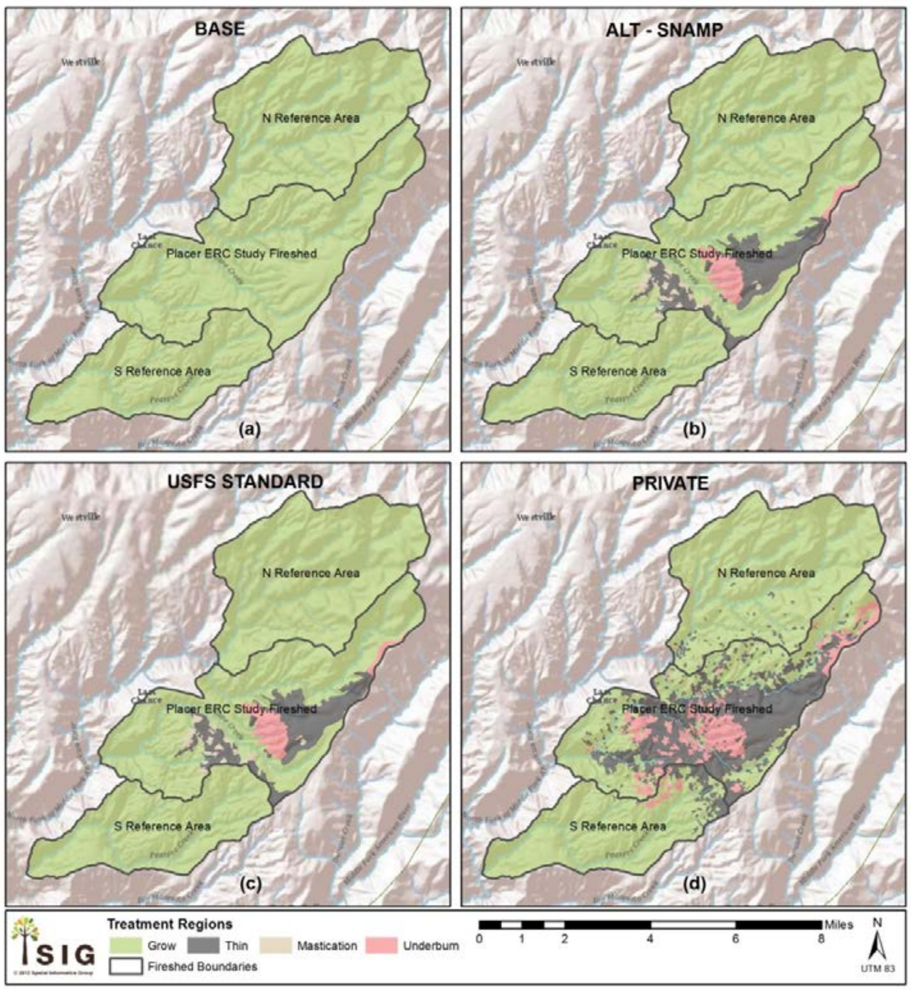


Figure 12: Base (no treatment) and three management scenarios developed for the Last Chance study area. General treatment type assignments are 1) Grow, 2) Thin, 3) Masticate and 4) Underburn. Scenarios are: (a) BAU – all areas are grown from base conditions without treatment; (b) Alternative – SNAMP and (c) USFS – Standard – layouts based on USFS recommendations; and (d) Private - Harvest – layout is an expansion of USFS recommendations intended to treat a larger proportion of the landscape

Fifteen possible treatment prescriptions were developed (Table 3) for use in tree growth (FVS), fire behavior (FlamMap), and fire emissions (Consume) models. These prescriptions reflected common forest management projects used in coniferous forests, and covered a range of low, moderate, and high treatment intensities as defined by their upper diameter limit, residual basal area, and/or trees per acre retained after treatment (Table 3). Under each management scenario, one prescription was selected from the 15 possible to be applied to each of the four general treatment type categories (Table 4). The Alternative-SNAMP scenario is intended to represent the lowest intensity on the landscape of the three treated scenarios, having a maximum upper diameter removal of 20” and residual canopy cover of 50% (Tables 3 and 4). The USFS-Standard scenario represents a more typical approach, allowing removal of trees up to 30” in diameter and a residual canopy cover of 40%. These guidelines are consistent with the 2004 Record of Decision of the Sierra Nevada Forest Plan Amendment (USDA Forest Service 2004), which helps guide fuel treatment implementation on federal lands. The Private-Harvest scenario is intended to represent a more intensive approach to fuel treatment, based on a commercial economic model, with no upper diameter limit or canopy cover retention restrictions (Tables 3 and 4). Tree growth, fire behavior, and fire emissions under these treatment scenarios were modeled over a period of 40 years in five year increments. Though specific treatments were selected from this list for this case study, other prescriptions can be selected under the framework for future evaluations.

Table 3: Fifteen possible prescriptions developed for use in three management scenarios

Num	Treatment	Description	FVS Implementation Notes
1	Control_Grow	No harvesting or surface fuel treatments.	Natural regeneration only, input on 10-year cycle
2	Thin_USFS_Low_Pile	Thin from below, pile and burn, and then grow over time. Thin up to 12" dbh, retain 60% canopy cover. Residual fuels piled and burned.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Regeneration and ingrowth every 10 years.
3	Thin_USFS_Med_Pile	Thin from below, pile and burn, and then grow over time. Thin up to 20" dbh, retain 50% canopy cover. Residual fuels piled and burned.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Regeneration and ingrowth every 10 years.
4	Thin_USFS_High_Pile	Thin from below, pile and burn, and then grow over time. Thin up to 30" dbh, retain 40% canopy cover. Residual fuels piled and burned.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Regeneration and ingrowth every 10 years.
5	Underburn	Surface fire with dry fuel conditions (early spring), 8mph windspeed, and an air temperature of 70 degrees F.	Fire in 2012. Assumes 100% burned. Natural regeneration every 10 years.
6	Mastication	Thin to 120 trees per acre with 90% cutting efficiency, leave residual fuels on site and masticate.	Species retention preferences are sugar pine, ponderosa pine, Douglas-fir and incense-cedar. Moves slash to ground level to simulate mastication. Grows plots with 10-yr ingrowth.
7	STS_Private	Single tree selection (STS) cut that harvests to the minimum of the FPRs. Residual basal area of 75 sq ft/ac. Residual fuels piled and burned.	Implements STS using the BDQ method to a residual basal area of 75 sq ft/ac using 90% cutting efficiency (assumes site II and III). Uses a Q of 1.2, 2 inch dbh classes for Q, and a dbh range of 10 to 30. Natural regeneration every 10 years.
8	Thin_USFS_High_Mastication	Thin from below, pile and burn, and then grow over time. Thin up to 30" dbh, retain 40% canopy cover. Residual fuels masticated.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Moves slash to ground level to simulate mastication. Grows plots with 10-yr ingrowth.
9	STS_Private_Mastication	Single tree selection (STS) cut that harvests to the minimum of the FPRs. Residual basal area of 75 sq ft/ac. Residual fuels masticated.	Implements STS using the BDQ method to a residual basal area of 75 sq ft/ac using 90% cutting efficiency (assumes site II and III). Uses a Q of 1.2, 2 inch dbh classes for Q, and a dbh range of 10 to 30. Moves slash to ground level to simulate mastication. Regeneration and ingrowth every 10 years.

Table 3 (continued)

Num	Treatment	Description	FVS Implementation Notes
10	Mastication_Underburn	Thin to 120 trees per acre with 90% cutting efficiency, leave residual fuels on site and masticate. Surface fire with dry fuel conditions (early spring), 8mph windspeed, and an air temperature of 70 degrees F.	Species retention preferences are sugar pine, ponderosa pine, Douglas-fir and incense-cedar. Moves slash to ground level to simulate mastication. Fire in 2012. Assumes 100% burned. Natural regeneration every 10 years.
11	STS_Private_Underburn	Single tree selection (STS) cut that harvests to the minimum of the FPRs. Residual basal area of 75 sq ft/ac. Surface fire with dry fuel conditions (early spring), 8mph windspeed, and an air temperature of 70 degrees F.	Implements STS using the BDQ method to a residual basal area of 75 sq ft/ac using 90% cutting efficiency (assumes site II and III). Uses a Q of 1.2, 2 inch dbh classes for Q, and a dbh range of 10 to 30. Fire in 2012. Assumes 100% burned. Natural regeneration every 10 years.
12	Thin_USFS_Low_RemoveSlash	Thin from below, then grow over time. Thin up to 12" dbh, retain 60% canopy cover. Residual fuels removed.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Slash removed. Regeneration and ingrowth every 10 years.
13	Thin_USFS_Med_RemoveSlash	Thin from below, then grow over time. Thin up to 20" dbh, retain 50% canopy cover. Residual fuels removed	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Slash removed. Regeneration and ingrowth every 10 years.
14	Thin_USFS_High_RemoveSlash	Thin from below, then grow over time. Thin up to 30" dbh, retain 40% canopy cover. Residual fuels removed.	Species retention preference during thin is black oak, sugar pine, ponderosa pine, Douglas-fir, incense-cedar and white fir. Regeneration and ingrowth every 10 years.
15	STS_Private_RemoveSlash	Single tree selection (STS) cut that harvests to the minimum of the FPRs. Residual basal area of 75 sq ft/ac. Residual fuels removed.	Implements STS using the BDQ method to a residual basal area of 75 sq ft/ac using 90% cutting efficiency (assumes site II and III). Uses a Q of 1.2, 2 inch dbh classes for Q, and a dbh range of 10 to 30. Slash removed. Natural regeneration every 10 years.

Table 4: Specific treatment prescriptions applied to general treatment type-areas under the three different management scenarios in this study.

Management Scenario	Treatment Type	Treatment Prescription
Alt-SNAMP	Grow	(1) Control_Grow
	Thin	(13) Thin_USFS_Med_RemoveSlash
	Masticate	(6) Mastication
	Underburn	(5) Underburn
USFS-Standard	Grow	(1) Control_Grow
	Thin	(14) Thin_USFS_High_RemoveSlash
	Masticate	(10) Mastication_Underburn
	Underburn	(5) Underburn
Private-Harvest	Grow	(1) Control_Grow
	Thin	(15) STS_Private_RemoveSlash
	Masticate	None
	Underburn	(11) STS_Private_Underburn

Step 2: Growth and Yield Carbon Simulations

The Forest Vegetation Simulator (FVS), Western Sierra Nevada variant (Dixon 2009), was used to simulate treatments, project growth and mortality, and track carbon pools under the BAU and each of the three management scenarios (Figure 12, Table 4) for the 40 year study period, in 5 year increments. The carbon

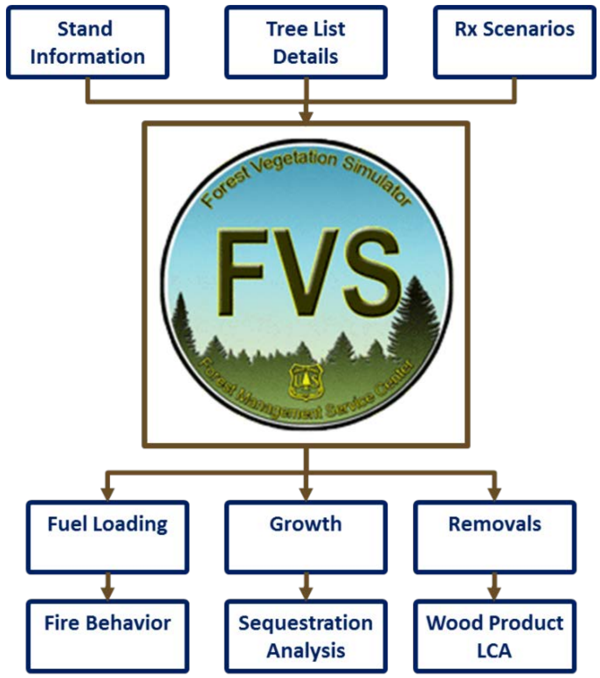


Figure 13: Tree growth and carbon sequestration estimation in the Forest Vegetation Simulator (FVS).

pools in FVS were tracked by the Fire and Fuels extension to FVS (Rebain 2010). While the live tree merchantable to whole above ground live tree portion was derived from the FVS model, the actual carbon estimates for live trees were derived from the Forest Inventory and Analysis (FIA) regional volume and biomass models (FIA 2010a, b). Figure 13 represents the general FVS process used. Table 6 summarizes total carbon removed from the study fireshed under each management scenario.

The carbon emission offset framework allows for various methods and assumptions in estimating different carbon pools. Table 5 lists the different carbon pools built-in, including pools of standing fire killed trees, which pools were estimated for Last Chance, and the sources of assumptions and equations used for each pool. Sources used included Forest Inventory and Analysis regional equations for the Sierra Nevada (for above and below ground live trees), US Department of Energy 1605(b) Program guidelines (for wood products in use and waste), and Forest Vegetation Simulator carbon reports using the Westside Sierra Nevada regional variant (for below and above ground dead trees, shrubs and grasses, and forest floor materials).

Table 5: Carbon pools estimated in the Carbon Emission Offset framework, with sources of assumptions and equations.

Carbon Pool	Assumptions & Equations	This Study
Above Ground Live $_{\text{Tree}}$ (AGt)	FIA regional equations	✓
Below Ground Live $_{\text{Tree}}$ (BGt)	FIA regional equations	✓
Wood Products In Use (WP_IU)	DOE 1605B 100yr	
Wood Products Land Fill (WP_LF)	DOE 1605B 100yr	
Below Ground Dead $_{\text{Tree}}$ (BGD)	FVS-West Side Sierra	✓
Above Ground Dead Standing $_{\text{Tree}}$ (AG_DS)	FVS-West Side Sierra	✓
Above Ground Dead Down $_{\text{Tree}}$ (AG_DD)	FVS-West Side Sierra	✓
Forest Floor (FF)	FVS-West Side Sierra	✓
Shrubs and Grasses (SH_GR)	FVS-West Side Sierra	✓

Table 6: Carbon (GHG – metric tons CO2e) removed from initial treatment applications under three management scenarios.

Management Type	TOTAL CARBON (C02e)	Acres Rx	CO2e / Rx Acres
Alt-SNAMP	11,035	2,633	4
USFS-Standard	45,685	2,633	17
Private-Harvest	300,812	5,949	51

Fire Hazard Assessment

A range of modeling tools are available to complete fire hazard assessments at the stand and landscape scales. Stand level analysis allow assessments of discrete areas of forest field data in programs such as the Forest Vegetation Simulator (FVS) and its Fire and Fuels Extension (FFE). To model fire hazard at the landscape scale, models such as FlamMap and Farsite, which can incorporate variations in topography, vegetation and weather are utilized. FlamMap and Farsite are spatial implementations of the Rothermel (1972) fire spread model. FlamMap (Finney 2006) estimates potential fire behavior as a "snapshot" in time under a given weather condition. It can also give an estimate of fire spread patterns under constant weather conditions using the Minimum Travel Time (MTT) algorithm (Finney 2001). Using this algorithm over a large number (e.g. thousands) of fires can give an estimate of conditional burn probability for a landscape – that is, the probability that a given point on the landscape will burn, assuming an ignition somewhere within the landscape. This is different from a more "absolute" probability, as described in the Fire Risk section below. RANDIG is a recent expansion of the FlamMap model that facilitates large numbers of simulations with the MTT algorithm, and can output the probability of wildfire of a given flame length or intensity for any point in the simulation landscape.

Approach: We used topographic data products from the US National Atlas (e.g. elevation, slope, aspect), as well as fuel characteristics (e.g. canopy cover, canopy base height, canopy height, surface fuel model, crown bulk density) derived from the previous steps as the foundational spatial layers for the BAU and three treatment management scenarios. Each scenario had 9 theoretical landscapes built for it – one pre-treatment (base) and 8 post-treatment (5 year intervals, 40 years total) for a total of 33 landscapes (the base landscape was the same for all). We used RANDIG to simulate 1,000 fires from randomly located ignition points on each of these 33 landscapes under 95th percentile weather conditions. Weather conditions were derived from historical data (1990-2008) at the Hell Hole Remote Automated Weather Station. For each landscape, we calculated average fire size, flame length, fireline intensity, rate of spread, and conditional burn probability within the study fireshed.

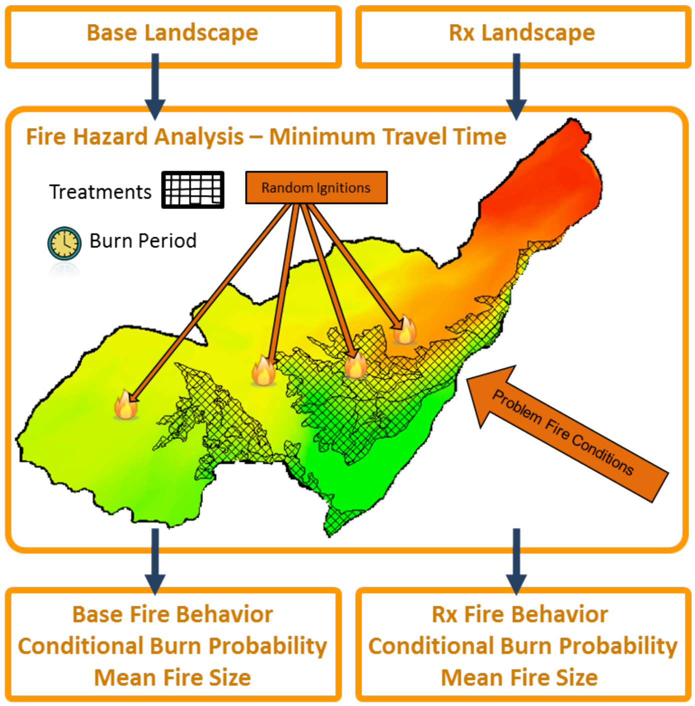


Figure 14: Example of 33,000 wildfire simulations run for the Last Chance study area.

For an individual fire ignition, fire shadow effects on emissions could theoretically be calculated by comparing fire size and behavior from the same ignition between an untreated (base) and a treated landscape. In this framework however, we simulate 1,000 randomly located fires across the fireshed. Because we randomly located these fires under each management scenario, we examined the collective effects of these thousand fires under each scenario, rather than comparing the same fire under the different scenarios a thousand times, which would not have been feasible. We examined the change in average fire size to quantify fire shadow effects (e.g. indirect emissions). Though calculated, we did not examine any changes in average fire behavior in untreated areas, because the Consume emissions model calculates emissions based only on fuelbed, acreage, weather conditions, and estimated percent canopy consumption (which is estimated in only three general classes in FlamMap).

Wildfire Risk Assessment

Fires occur as a function of a "fire regime triangle" of factors that regulate long-term fire activity: ignition sources, vegetation type, and climatic conditions during the fire season (Figure 15; Moritz et al. 2005). Spatial and temporal variation in these three factors interact, and the outcomes – the area burned, burn severity, seasonality, fire size, and fire intensity – are well described as stochastic events regulated to varying degrees by different factors in the fire regime triangle. Patterns of fire events in a specific location over time are used to describe its fire regime. For example, weather conditions and patterns vary from year to year, often in multi-year cycles (Kitzberger et al., 2007), such that long-term data are required to estimate the boundaries of historical variation in fire activity.

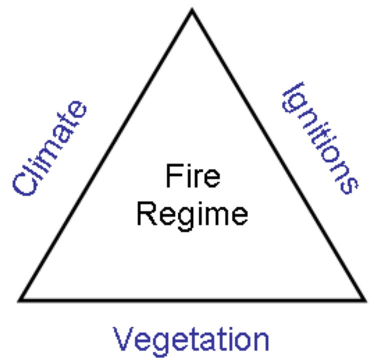


Figure 15: Fire regime triangle, from Moritz et al. 2009.

Where fuel treatments can be shown to reduce emissions of atmospheric carbon or other GHGs, carbon emission offsets have been proposed as one way of reducing operational costs while providing added value ecosystem services. If carbon emission offsets are to be given for these treatments, it is necessary to establish a robust estimate of the baseline fire return intervals (i.e. from long-term mapped fire occurrence probabilities) for gauging the effectiveness of treatments at reducing carbon emissions. This is because some portions of the landscape are in more fire-prone environments than others, which means that some fuels treatments are more likely to achieve their emissions reduction benefits than others. Long-term expected fire occurrence probabilities are also necessary for assessing the relative merits of forest carbon sequestration projects (i.e. through quantifying environmental uncertainty and potential losses over 100 years), although establishing these baseline metrics is not carried out routinely (e.g., Richards and Stokes, 2004).

The risk of fire occurrence for any given point on a landscape can be estimated in a number of ways, though there is no generally accepted method in use. One can examine historical patterns of ignitions and fire areas across the landscape to make an estimate of ignition probability and wildfire frequency at a given location, though this approach is based solely on relatively short historical record (ca. 120 years in California), the quality of which deteriorates the farther back one looks. Additionally, this method is based only on actual previous occurrences of fire, a somewhat stochastic process in space and time which is driven by both endogenous and exogenous factors. Examining pre-historic fire regimes through techniques such as tree ring analysis, stand age analysis, and paleoecological studies can give us information as to probabilities prior to Euro-American impacts, but faces the same issues as the historical methods and is further diluted by the lack of detailed spatial information found in historical records. Fire behavior simulation models can estimate a "conditional" burn probability, contingent upon a fire occurring in the study area. That is, it estimates the probability that a given point within the study area will burn during a fire started somewhere within the study area. Finally, recent work has begun to estimate fire probabilities without this condition by examining the spatial distribution of fire risk as a process regulated by a variety of exogenous and endogenous factors and environmental characteristics, similar to wildlife habitat (e.g. Moritz et al. 2009, Moritz and Parisien, 2009).

A variety of statistical approaches has been developed at different spatial scales to relate fire occurrence probability at a location to variability in environmental characteristics (e.g., McKenzie et al., 2000; Cardille et al., 2001; Parisien and Moritz, 2009; Krawchuk et al., 2009). Such models can consider a wide range of predictor variables, including vegetation characteristics (e.g. cover type, productivity), topographic factors (e.g. slope, aspect, and landscape position), climate (e.g. averages and seasonality), ignition potential, and anthropogenic factors (e.g. human population pressure and land-use) as candidates to describe spatial variation in long-term fire occurrence probabilities. Many open questions remain, however, about the best variables to use, inherent sensitivities to modeling decisions, and techniques for training and testing such models. Parisien and Moritz (2009) developed a scientifically rigorous method of quantifying baseline fire occurrence rates, based on long-term fire patterns (i.e. multiple decades) and spatially explicit environmental variables, which was applied to regions of California and can be extended to the entire western U.S.

Approach: We examined the probability of wildfire occurrence on this landscape in several ways. First, we estimated the historical fire return intervals likely for this location and vegetation type. An analysis of tree ring fire scars in nearby Blodgett Forest Research Station estimated fire in mixed conifer forest types similar to Last Chance as having occurred every 5-15 years at low intensity (Collins and Stephens, 2004). Other studies from the North and Central Sierra Nevada and in similar forest types suggest similarly frequent fire return intervals (Skinner and Chang, 1996, Swetnam et al., 1998, Taylor, 2000; Taylor and Beaty, 2005). The Blodgett estimates made by Collins and Stephens (2004) were geographically the closest to this study for the mixed conifer forest types, demonstrating point fire return intervals (intervals observed at individually sampled trees) of 9-15 years. We therefore estimated the representative pre-historic fire return interval for the majority of forest types on the Last Chance study area to be 15 years. A fire occurring at a given point on the landscape once every 15 years yields an annual probability of 6.67%.

We then used the Maxent statistical framework, a recently developed probabilistic distribution modeling tool (Elith et al., 2006; Phillips et al., 2006), to generate spatially explicit and variable fire probability maps for Placer County, California. Maxent estimates the target distribution by finding the distribution of maximum information entropy (i.e. closest to uniform) subject to the constraint that the expected value of each feature under this estimated distribution matches its empirical average. This approach requires fire history records (locations) for an area as training data and spatial environmental layers as independent predictor variables of fire presence, establishing complex statistical relationships between fire occurrence and the environmental variables that characterize the most suitable locations for its occurrence. No fire absence data are required, as would be necessary for many distribution mapping tools (Philips, 2008). Special features of Maxent, including regularization and cross-validation of data, help to prevent overfitting of training data and allow the generation of robust fire-probability maps. The methodology employed here could thus be extended to any other region with appropriate fire history and environmental data (e.g. Parisien and Moritz, 2009; Krawchuk and Moritz, 2009; Krawchuk et al., 2009).

Training data for Maxent were obtained from fire history maps (1900-2007)(CalFire FRAP, 2010) and climate data (PRISM at ~800 meter resolution and Daymet at 1-km resolution) covering Placer County. Monthly and annual means of environmental variables were sampled within the area burned by each fire for the period under consideration. Initial modeling used 32 environmental variables (Tab. 1) as predictors (independent variables), constituting the full model. Subsequent correlation analyses among these 32 variables led to the development of a reduced, 15-variable model. The reduced set included the minimum and maximum monthly values of temperature, precipitation, precipitation frequency, relative humidity, solar radiation, potential evapotranspiration, water balance, and cumulative annual deficit of soil moisture. Northern California was determined to be an appropriate geographic region from which to develop models. Final Maxent models were based on an average of a suite of four models: two different variable sets (32-variable ensemble and 15-variable ensemble) and two different fire size thresholds in each region (1,000 acre and 5,000 acre).

Maxent's logistic output is a relative fire occurrence probability, arbitrarily scaled between zero and one; therefore, it is not a true annual burn probability, nor necessarily a probability of burning over the time period from which the training data were collected. The results must be rescaled using fire history data to be converted to meaningful fire occurrence probabilities. The approach used here involved determining the mean annual burn rate from fire history data for the training area, and then dividing this by Maxent's mean fire probability value for the same area, to determine a conversion factor between the two products. Applying the derived ratio to the Maxent relative probability occurrence map results in the appropriate fire occurrence probability map. This result can also be inverted to give an expected fire return interval.

California's fire history data are considered fairly reliable back to 1950, but using a time window of 1950-2007 to determine an annual burn rate provides a relatively low estimate of annual burning compared to a window

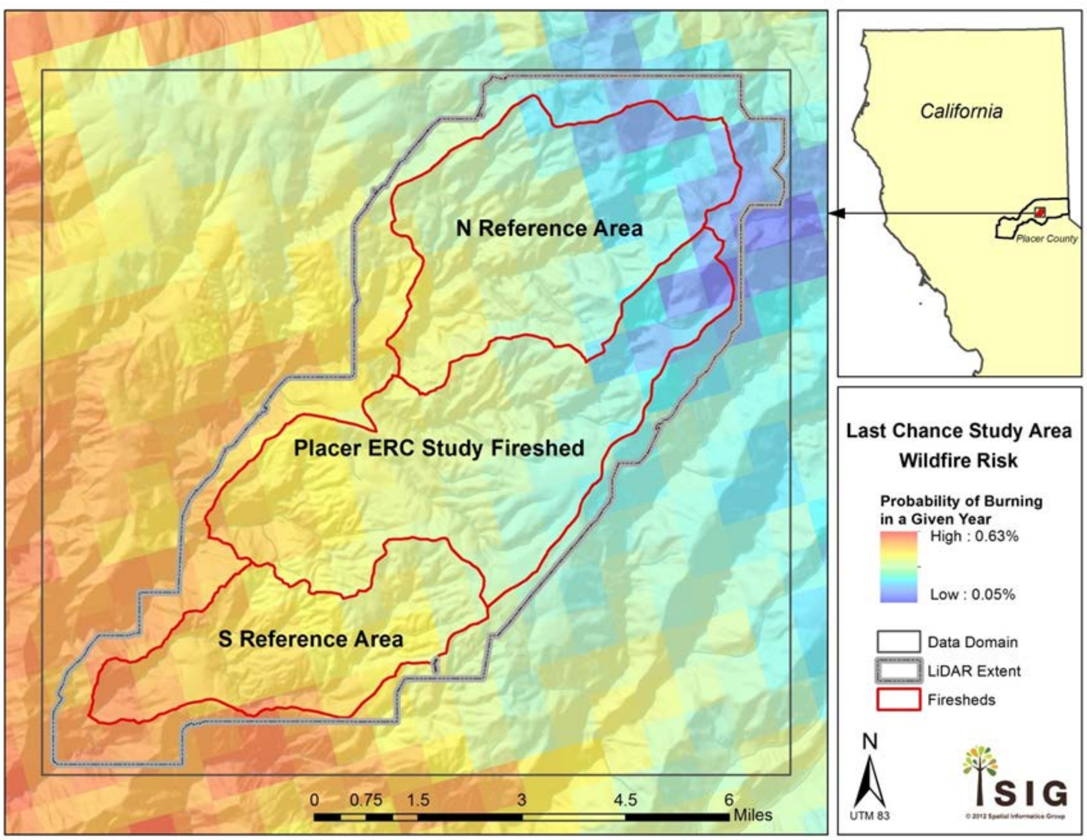


Figure 16: Wildfire risk analysis for the Last Chance study area, using the Maxent model. Maxent outputs calibrated to fire history data from 1950-2007.

that includes only more recent years. Fire reporting has become more accurate (e.g., older data may be missing fires), and recently, fire activity has increased perhaps due to changes in the climate. Using the 2001-2007 time period thus provides a more recent higher burn rate that can be thought of as an upper estimate of annual burning. Fire history data from two time windows (1950-2007 and 2001-2007) were used to generate two conversion factors that could be applied to the Maxent relative probability outputs to get upper and lower estimates of annual burn probabilities. These results were then inverted to give expected fire return interval products. In addition to considering the average output of these four models (Figure 16) we generated approximate 95% confidence interval products for each model based on the standard deviation (SD) output from Maxent (mean +/- (1.96*SD/root n)) where n refers to the number of bootstrapped replicates in a Maxent model run. These upper and lower confidence interval products from each model were then separately averaged to generate multi-model upper and lower confidence interval products. Further details on model fitting methods can be found in Parisien and Moritz (2009). For the calibration period of 1950-2007, fire probabilities in a given year for the study fireshed were found to range from 0.20% to 0.48%, with a mean of 0.38% (Figure 16), representing an average fire return interval of 263 years.

We used these estimates of fire frequency to apply fire risk to the fireshed emissions estimates. The scale of evaluation for the carbon emission offset framework is the fireshed, i.e. projects will be evaluated at the fireshed level. Our goal, therefore, was to find an appropriate fireshed-wide estimate of fire risk. Based on the above evaluations, we applied three fire frequencies to the study fireshed: 1) 15 year return interval ("restored"), a frequency which might be expected if fire were restored to the landscape at its pre-historic frequency; 2) 200 year fire return interval ("contemporary"), a frequency that is representative of contemporary fire regimes over the last century; and 3) 50 year return interval ("intermediate"), a frequency that might be a more realistic estimate to implement in the current environment than the fully "restored" frequency. We applied these in two ways.

First, we applied a "constant" risk model, wherein the probability of wildfire remains constant through time. We derived annual probability of wildfire for the three frequency scenarios above (6.67%, 2.00%, and 0.50% for "restored", "intermediate", and "contemporary" respectively), then calculated the five-year probability of wildfire based on standard probability theory for an event happening at least once in a given period of time, using the following formula:

$$q = 1 - (1 - p)^n$$

where: q is the probability of an event happening at least once in n units of time, and p is the probability of the event happening in one unit of time (Gotelli and Ellison 2004, Rhodes and Baker 2008). In our scenarios:

Restored frequency: $q = 1 - (1 - 0.0667)^5 = 0.2918$
Intermediate frequency: $q = 1 - (1 - 0.0200)^5 = 0.0961$
Contemporary frequency: $q = 1 - (1 - 0.0050)^5 = 0.0248$

However, whether the source is pre-historic frequency estimates from tree-ring analysis or statistical examinations of spatial variation, the annual probability of wildfire occurrence for a given point on the landscape typically has some mean or median expected value and variation around this probability. For example, if a point on the landscape has an estimated mean fire return interval of 15 years, there is some probability that it will happen sooner, some probability that it will happen at or near the mean, and some probability that it will happen later than the mean. Because we are examining the study area over a 40 year period, and because there will surely be natural variation in the frequency of fire there, the challenge is to integrate a naturally stochastic temporal component into the other elements of this avoided emissions analysis.

To accomplish this, we also applied a temporally "variable" fire risk model. We selected the Weibull distribution, a flexible statistical distribution that has long been used in fire history studies, as a model for our temporal variation in fire probabilities. For more background on how this distribution relates to fire hazard and fire frequencies, Moritz et al. (2009) provides a recent review. In our application, the flexibility of the function describing the Weibull distribution is helpful, being bounded at zero (i.e., negative fire probabilities are impossible) and allowing one to simulate how effective management may be at actually achieving the desired mean fire interval across the landscape. This can be simulated through the "scale" and "shape" parameters of the Weibull distribution, which can be used to control how long and how variable fire intervals tend to be, respectively. The two-parameter Weibull probability density function is defined as:

$$f(t) = (ct^{(c-1)})/b^c * \exp(-(t/b)^c)$$

where b is the scale parameter, c is the shape parameter, and t is time. We applied the following parameters for our frequency scenarios:

Table 7: Weibull distribution parameters used for three fire frequency scenarios in the variable fire risk model.

	Weibull Parameter		
Frequency Scenario	***b***	***c***	**Median**
Restored	18	2	14.99
Intermediate	60	2	49.95
Contemporary	240	2	199.81

We chose a shape parameter of 2 in order to more accurately simulate fire return interval distributions, which typically are positively skewed, and chose the scale parameter to give the desired median return interval (Figure 17). The assumption in this risk model, when applied to this framework, is that if the treatment occurs at

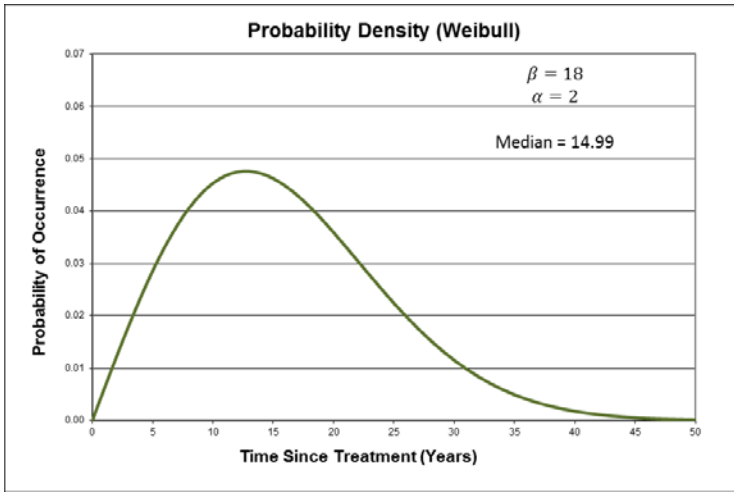


Figure 17: Weibull distribution of fire probabilities, with a scale parameter of 18 and a shape parameter of 2, yielding a median fire return interval of 15 years. Note the long tail characteristic of fire return interval distributions.

the beginning of a fire return interval, i.e. the probability of wildfire is zero at t=0. We apply the cumulative probability at each time step to calculate benefits and liabilities, which assumes that no fire has occurred in the fireshed to that point.

Wildfire Emissions Estimation

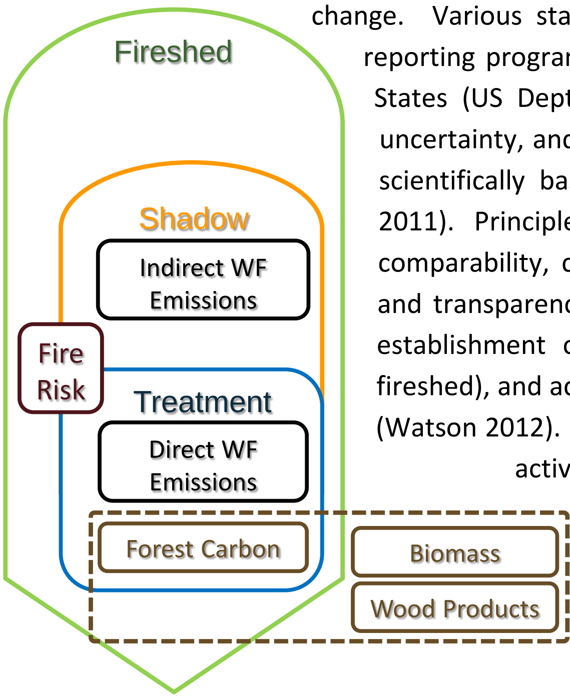
Fire emissions models such as Consume (Prichard et al., 2010a), the Fire Emissions Production Simulator (FEPS) (Anderson et al., 2004), and the First Order Fire Effects Model (FOFEM) (Reinhardt et al., 1997) have developed in parallel with fire behavior modeling, but have different data requirements. This is primarily due to the fact that accurate emissions estimations often require different descriptions of fuelbeds, than do fire behavior prediction models. They also require coupling of frontal surface fire, post-frontal surface fire, and crown fire in making estimates. Fire behavior fuel models are primarily designed for modeling either surface or crown fire behavior (e.g. fire at the flaming front). Pollutant emissions, however, are not only the result of fire at the flaming front, but are also greatly affected by post frontal combustion (e.g. smoldering), burning of jackpot accumulations, and other combustion processes.

Consume is a Windows-based computer application that can predict fuel consumption, pollutant emissions, and heat release based on a number of factors including fuel characteristics and environmental conditions (Prichard et al., 2010a). Among the primary benefits of this model is that it allows for very detailed specification of the fuelbed. Consume uses the Fuel Characteristic Classification System (FCCS) model for fuel classification. It accounts for virtually the entire range of vertical fuel strata, including duff, basal accumulations, squirrel middens, litter, ground lichen and moss, sound and rotten dead wood, stumps woody fuel accumulations, grasses and herbs, shrubs, trees, snags, and ladder fuels, with different algorithms for computing emissions from each of these strata. Consume also has a useful hierarchical project structure which allows the user to specify different fuelbeds within project units, and different units within a project. Users can customize fuelbeds to account for local variation. Consume calculates and summarizes fuel consumption, emissions and heat release in various ways. Consumption can be summarized by combustion phase (flaming, smoldering, or residual), or 1,000-hr fuel moisture categories. Emissions can be summarized by combustion phase, 1,000-hr fuel moisture categories, or fuelbed stratum. Emissions estimates are made for total particulate matter (PM), particulate matter less than 10 (PM_{10}) and 2.5 ($PM_{2.5}$) microns, carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4) and non-methane hydrocarbons (NMHC).

Approach: Surface fuel model and canopy characteristic data derived in the fire behavior and tree growth steps (described above) were translated into FCCS fuelbeds for each of the 33 landscapes for Last Chance (1 Base landscape and 8 treatment landscapes per management scenario) using the methods described in Collins et al. (2010). For each landscape, total area of each unique fuelbed within the study fireshed was calculated and input into the model, which was run in batch mode using RAWS derived fuel moistures consistent with 95 percentile weather conditions. Outputs from Consume were imported into an MS Access Database, where the results were parsed and summarized for each management scenario. Total carbon in emissions was also calculated in the database.

Carbon Accounting

The term carbon accounting in forest management refers generally to the process of quantifying baselines for and changes in stocks, sources, and sinks of carbon and other GHGs that may contribute to global climate change. Various state, federal, and international organizations have established reporting programs and guidelines for carbon accounting, including the United States (US Dept of Energy 2005), although issues such as model selection, uncertainty, and definitions of carbon pools can make consistent, comparable, scientifically based carbon accounting difficult at best (Malmsheimer et al. 2011). Principles of good accounting practice include accuracy and precision, comparability, completeness, conservative estimation, consistency, relevance and transparency (Watson 2012). Reliable forest carbon accounting requires establishment of a discrete accounting area (e.g., the Last Chance study fireshed), and accounting for carbon stocks, emissions, and emission reductions (Watson 2012). In examining fuel treatments as a potential emission reduction activity or sequestration mechanism, it is important to consider not only carbon removed from the forest, but also avoided wildfire emissions (Ager et al. 2010, Hurteau and Brooks 2011) and wood product life cycles (Smith et al. 2005).



Approach: The GHG accounting process developed for the carbon emission offset framework integrates the results from all of the previous steps, in order to evaluate the net effect of a fuel treatment scenario on GHG emissions within the study fireshed. Benefits and liabilities can result from various elements of the management scenario. The primary effects considered here are forest growth and carbon sequestration, wood and biomass removal and utilization, and wildfire.

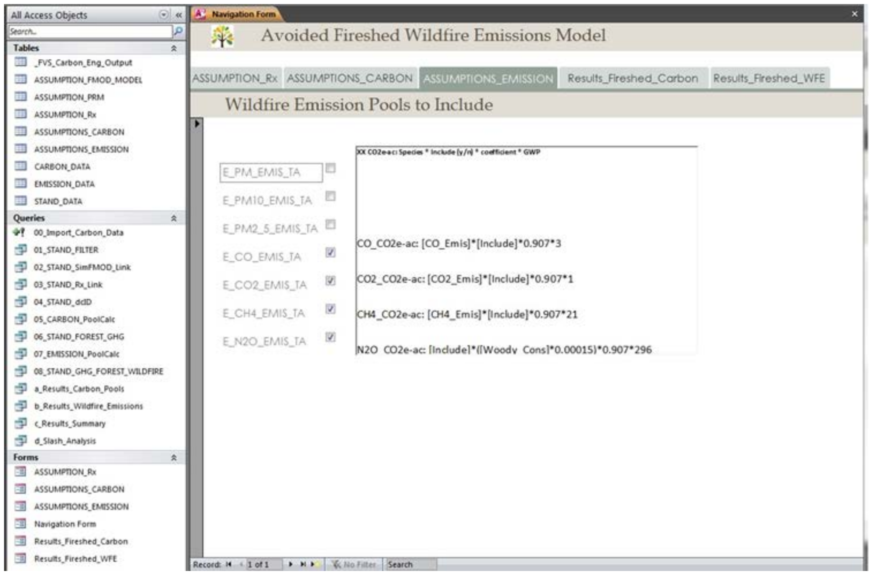
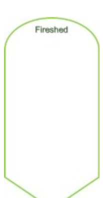


Figure 18: Access database developed to summarize and query emissions results.

The impact of fuel treatments on emissions was quantified using standard principles in carbon market accounting used for determining credits. These approaches utilize a business as usual baseline compared to some alternative scenario. This baseline can be fixed (recorded to one period in time) or dynamic (moves in space and time). While the fixed baseline approach is less complex to implement in a protocol, it does not accurately quantify the additionality question posed in the beginning of this research project and thus the dynamic baseline approach was utilized. It was also recognized that there are many variables that are included in this approach and a sensitivity analysis would shed light on the overarching impacts. The scenarios were developed to produce a spectrum of results that matched real potential operational activities within this landscape. The net benefit of treatments on avoided wildfire emissions is quantified by integrating the impacts of wildfire treatments on multiple carbon pools compared to a business as usual baseline. This framework incorporates treatment effects within defined forest carbon pools, the net impact of treatments on those carbon pools, the impact of direct carbon emissions from wildfire amortized by the risk of wildfire, the impact of indirect carbon emissions from wildfire amortized by the risk of wildfire, and a localized life cycle assessment that includes biomass utilization. The emissions associated with the recovery and transportation of biomass and wood products are not incorporated in this analysis since they are likely insignificant in comparison to other sources (Springsteen et al, 2011). This framework also does not incorporate an assessment of fossil fuel displacement, and assumes that, based on a policy decision; biomass is a carbon neutral for of energy. The additionality of carbon was determined by directly comparing the temporal difference between alternative scenarios to a dynamic business as usual baseline. This methodology was conducted for all three scenarios with the results compared.

A) Fireshed:



The fireshed is the basic unit of measure used in this accounting framework. It is a scale that allows the ecologically relevant integration of wildfire risk, wildfire hazard, and forest carbon accounting. Firesheds are delineated as described above, vegetation within firesheds is quantified and classified, and the results from each of the previous sections are geo-summarized at the fireshed scale into common units for use in the analytical framework.

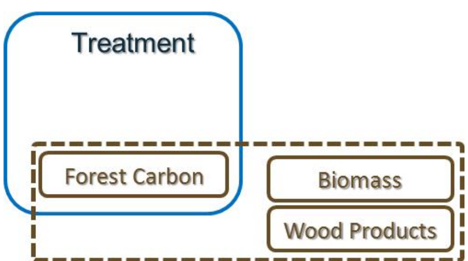
B) Net Forest Carbon Emission (GHG / fireshed acre)

The type and intensity of treatments have several effects on this framework. Treatments not only directly change the amount of forest carbon in the fireshed, but treatment type also influences the amount of merchantable and non-merchantable wood that comes out of the fireshed. This in turn impacts the emissions associated with the wood product LCA.

The next step in this accounting framework is to determine the total amount of forest carbon that remains in the fireshed over time after treatments. Several elements are integrated in this measure including growth, yield, and regeneration. The resulting value is a measure of average forest GHGs stored or emitted per fireshed acre, where a net positive value represents an emission, or GHGs assumed lost to the atmosphere, and a net negative value represents GHGs sequestered, or avoided emissions. After harvest, the carbon sequestered in the forest is calculated as the forest grows over time. Carbon stored in the untreated landscape (BAU scenario) is compared to carbon stored in the treated landscape, under the various management scenarios. This is achieved using the following steps:

- Quantify the sum of forest carbon under the BAU (Business-As Usual) scenario for the selected pools described in the above section for each temporal period and normalize by the area of the fireshed.
- Quantify the sum of forest carbon under the alternative scenarios for the selected pools described in the above section for each temporal period and normalize by the area of the fireshed.
- Quantify the net difference between the baseline and alternative scenario. This becomes the net forest carbon emission. For a given time period and management scenario, a net positive emission means that the managed landscape stored less carbon than the untreated landscape (BAU scenario).

C) Forest Carbon Wood Products Life Cycle Analysis (GHG / fireshed acre)



Understanding the fate of biomass removed from the fireshed is a critical component of this framework. There is a substantial amount of biomass removed from the fireshed and its fate has a significant impact of the overall results. Several assumptions are made in this assessment, first that there is a viable biomass industry within reach of the fireshed, second that the merchantable wood (sawlogs) will be sent to a local mill, and third that the treatments will be implemented fully within the firesheds. Finally, it is assumed that the collection, processing and, transportation and of biomass is not significant compared to the magnitude of the other elements of this framework. Several more assumptions are parameterized as part of this framework. The emissions from wood products are determined for both merchantable and non-merchantable material removed from the fire shed. The total avoided wood product emissions is determined by summing up the avoided emissions from the non-merchantable and merchantable wood product life cycles. Below is a description of this process.

Non-Merchantable Wood Products (GHG / fireshed acre)

Non-merchantable volume of wood was calculated by comparing treatments of a defined intensity that had the slash remain in the fireshed vs. the same treatments that has the slash removed from the fireshed. This calculation was only completed for the first time period after harvest (assuming a one-time treatment at the beginning of the study period) using the following steps:

- Quantify Non-merchantable volume by comparing treatments of a defined intensity that had the slash remain in the fireshed vs. the same treatments that has the slash removed from the fireshed.
- Since treatments were not consistent across the entire fireshed the results from the previous step was calculated for all treatment combinations then summed and divided by the total fireshed area to get the GHG / fireshed ac units.
- The resulting value was then multiplied by a biomass efficiency coefficient that determined how much of that biomass made it into the facility from the landing. For this analysis we used a value of 95% (Personal communications with Tad Mason, TSS Consultants).
- A life cycle analysis was applied to the utilized biomass volume to account for fossil fuel displacement and fossil fuel requirements for biomass waste processing and transport.
- The resulting pool was then included as a static pool that carried through the analysis because that carbon was sequestered by the biomass energy policy assumption described above.

In short, since that biomass was used for energy, it replaced a fossil fuel emission and thus is determined to be carbon neutral allowing this framework to use it as a sequestered pool for the duration of this analysis (40 years).

Merchantable (GHG / Fireshed-ac)

Merchantable volume was calculated directly from the FVS simulations. This volume was then used to determine life cycle emissions from wood products for a period 40 years. This calculation was only completed for the first time period after harvest (assuming a one-time treatment during the study period) using the following steps:

- The amount of merchantable material that was removed from the fireshed was determined by comparing the merchantable volumes between the baseline and alternative treatment.
- This total starting volume arriving at the mill was modified by a mill efficiency coefficient that estimates the total amount of merchantable material that went to wood products. The mill efficiency for the study area was determined to be 67% (Personal communications with Tad Mason, TSS Consultants).
- The sequestration (and emissions) from the the wood product was estimated using a wood product life cycle curve specific to the fireshed location and wood product material type (Smith et al. 2005).
- The mill wood waste quantity was multiplied by a biomass efficiency coefficient that determined how much of the wood waste made it into biomass energy utilization. For this analysis we used a value of 75% (Personal communications with Tad Mason, TSS Consultants).

- A life cycle analysis was applied to the utilized mill wood waste biomass volume to account for fossil fuel displacement.
- A life cycle analysis was also applied to the mill waste to account for degradation of waste and carbon release.
- The resulting merchantable wood product life cycle avoided emissions was determined by summing up the individual elements

D) Fire Risk (GHG / Fireshed-acre)

Fire risk is used to discount the potential wildfire emissions savings from a given fire by the probability of the fire occurring. Fire risk was determined several different ways for the study including the present (historic) return interval that incorporates suppression (roughly 0.5% a year) to a prehistoric fire return interval (prior to Euro-American settlement) of roughly 6.7% or once every 15 years). To account for temporal variability, the probability of wildfire at each time step by assuming fire frequency could be represented adequately by the Weibull distribution. The framework allows for the fire risk to change, either over time to account for a transition, or due to varying methods of estimation. The framework also allows the risk to be determined by scenario to compare alternatives.

E) Direct Wildfire Emissions

Avoided direct wildfire emissions are defined as the emission reductions observed or expected within a treatment area, and are a direct result of a reduction in fuel loads, fuel arrangements, and resultant fire behavior within those areas. The reduction of the emissions was calculated using the dynamic baseline assessment as described above. The analysis was conducted for each timestep in the complete time period amortized by the risk of fire using the following steps:

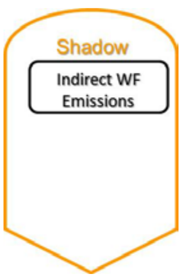
- Potential average wildfire emissions (GHG/acre, calculated in Consume) were determined for the entire fireshed using the BAU (business as usual) scenario.
- Potential average wildfire emissions (GHG/acre, calculated in Consume) were determined for the entire fireshed using each of the management scenarios.
- Net Direct Wildfire Emissions for each management scenario were estimated by taking the difference in values between the base and management scenarios. The results were then normalized by the fireshed area.
- The results were then discounted by the probability of wildfire occurring as defined above.

F) Treatment Shadow

A fuel treatment shadow, or treatment shadow, refers to the area outside fuel treatments that experiences altered or reduced fire behavior as a result of the treatment. Treatment shadows have not been treated per se, but benefit from the treatment nonetheless. For example, treatments may reduce the ultimate size of the fire, or may cause reduced fire effects in the area behind the treatment (relative to the direction of fire movement, typically the leeward side – see Finney et al. 2005). Treatment shadow effects are the changes in fire behavior or emissions associated with treatment shadows. Avoided indirect wildfire emissions are those emissions avoided as a result of treatments, but which are outside the treatments themselves, and are a net benefit to the framework. The method used to quantify the influence of the shadow area is described in the steps below:

- Temporal landscape files (one every five years) were built for each scenario.
- RANDIG was run using the problem (95th percentile) weather conditions (the same fire behavior weather parameters used in the emission model) for each of the landscapes.
- Results from the simulations (fire size and behavior) were compiled.
- Average fire size was calculated for the BAU (business as usual) scenario for each time period.
- Average fire size was calculated for each of the management scenarios for each time period.
- The change in average fire size was quantified in reference to the BAU (business as usual) scenario for each of the time periods. This proportion is called the “treatment shadow coefficient”.

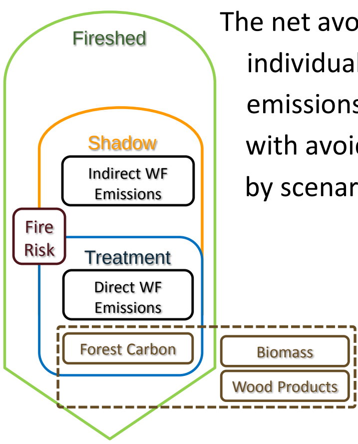
G) Indirect Wildfire Emissions



Avoided indirect wildfire emissions are those emissions avoided as an indirect result of treatments within the fireshed (e.g., outside the treatments themselves) and is a net benefit to the framework. The reduction of the emissions was calculated using the dynamic baseline assessment as described above. The analysis was conducted for the complete time period amortized by the risk of fire using the following steps:

- Indirect emissions were determined by multiplying the fire shadow coefficient by the per-acre emissions associated with the baseline.
- The results were then discounted by the probability of wildfire occurring as defined above.

H) Net Avoided Emissions from Treatments



The net avoided emissions are determined by summing up the emissions associated with the individual elements of the framework. The results are presented as atmospheric emissions and sinks. Forest emissions are compared to avoided wildfire emissions along with avoided emissions from wood products and bioenergy. The findings are summarized by scenario.

Findings

All Scenarios: Fire Risk

Under restored fire risk (15 year MFI), the variable (Weibull) probability of wildfire increased from 7.4% after 5 years to 50.1% at 15 years, and was near 100% by year 40. Using a restored/constant risk model, the five-year probability of wildfire was 29.2%. Under intermediate fire risk (50 year MFI), the variable probability of wildfire increased from 0.7% at year 5 to 35.9% at year 40, while the intermediate/constant risk model resulted in a 5 year probability of 9.6%. The contemporary fire risk model (MFI of 200 years), produced a variable risk of 0.04% at year 5, increasing to 2.7% at year 40. Constant fire risk under contemporary conditions was 2.5% for a five year interval (Table 7).

Table 8: Probability of wildfire at 5 year time steps, estimated for three fire frequency types using a temporally variable model (Weibull) and a fixed/constant model.

PROBABILITY OF FIRE								
	Year							
Frequency - Model	5	10	15	20	25	30	35	40
Restored (MFI 15)								
Weibull	7.43%	26.56%	50.06%	70.90%	85.47%	93.78%	97.72%	99.28%
Constant	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%
Intermediate (MFI 50)								
Weibull	0.69%	2.74%	6.06%	10.52%	15.94%	22.12%	28.84%	35.88%
Constant	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%
Contemporary (MFI 200)								
Weibull	0.04%	0.17%	0.39%	0.69%	1.08%	1.55%	2.10%	2.74%
Constant	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%

Baseline Scenario: Base–BAU

The Base – BAU scenario established baseline carbon stocks and emissions over the 40 year study period. Without fuel treatment or management activity, GHGs stored in the various pools estimated (Table 5) increased in total from approximately 230 to 430 tons GHGe per acre across the study fireshed. Wildfire emissions from simulated wildfire on the Base landscape increased from 55 to 72 tons/acre (Figure 19).

Table 9: Expected total sequestration and wildfire emissions (GHGe / fireshed acre) for the Base-BAU scenario (control / no management activity). Values (metric tons GHGe) are in terms of emissions, where positive values represent emissions or equivalent carbon loss, and (negative) values represent carbon sequestered or emissions avoided

BASE - BAU									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
BASE - Direct Wildfire Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71

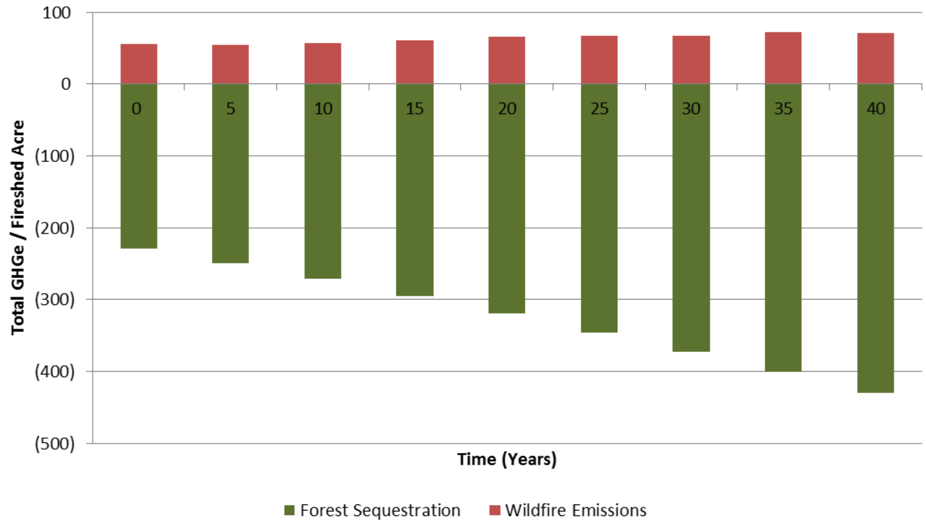


Figure 19: Expected total sequestration and wildfire emissions (GHGe / fireshed acre) for the Base-BAU scenario (control / no management activity). Values (metric tons GHGe) are in terms of emissions, where positive values represent emissions or equivalent carbon loss, and (negative) values represent carbon sequestered or emissions avoided.

Management Scenario: Alternative-SNAMP

Forest Carbon

After treatment, forest growth modeling under the Alt-SNAMP scenario showed a growing deficit of sequestered GHGs when compared to the baseline (Base-BAU) over the study period. The deficit of stored GHGs between the Alternative - SNAMP and Base - BAU scenarios grew from 7 tons GHGe / acre 5 years post treatment, to 12 tons /acre 40 years post treatment, although this deficit remained roughly proportional to the total volume of stored forest carbon (about 3% of baseline) (Table 9). These amounts are considered as net GHG losses, but can be offset by GHGs that become stored in wood products (durable and waste), biomass used in energy production, and changes in expected wildfire emissions.

Table 10: Forest carbon stock and growth for the Alt-SNAMP scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**

Wood Products and Biomass Energy

The Alt-SNAMP scenario resulted in approximately 1.1 tons/acre and 3.0 tons/acre of GHG removed from the forest as merchantable and non-merchantable wood, respectively. Accounting for biomass utilization, mill efficiency and wood product decay in the LCA, wood removal resulted in stored or offset GHGs of approximately 1.3 tons/acre after 5 years, declining to 1.0 tons/acre after 40 years. Offsets from these framework elements were never enough to negate the loss of carbon resulting from removal (treatment) over the course of the study period (Table 10).

Table 11: Wood product life cycle analysis results for the Alt-SNAMP scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
					Time (yrs)				
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**

Wildfire

Direct wildfire emissions were reduced after treatment (year 5) by 0.3 tons/acre, but showed a slight increase (0.04 tons/acre) at year 10. Direct emissions were reduced in years 15-40, varying from 1.3 to 2.6 tons/acre. The Alt-SNAMP treatments reduced average fire size in the fireshed by 56% at year 5. This effect began to diminish at year 25 (36% reduction), and was almost gone by year 40 (3% reduction).

Accounting for direct wildfire emissions, treatment shadow effect, and fire risk, the Alt-SNAMP scenario with restored fire frequency (variable risk) resulted in a net GHG benefit from avoided wildfire of 2.3 tons/acre 5 years post treatment, increasing to 28.0 tons/acre 25 years post treatment, then decreasing to 4.0 tons/acre at 40 years. Using the constant fire risk model, the Alt-SNAMP scenario under restored fire frequency provided a net benefit in avoided wildfire emissions of 9.0 tons/acre at year 5, increasing to 11.1 tons/acre at year 20, decreasing to 1.2 tons per acre at year 40. Under intermediate frequency (variable risk), Alt-SNAMP provided net avoided wildfire benefits of 0.2 tons per acre at year 5, increasing to 5.6 tons/acre at year 30, then decreasing to 1.5 tons per acre by the end of the study period. Intermediate frequency using the constant risk model resulted in net avoided wildfire benefits of about 3 tons/acre for the first 30 years, then decreasing to

0.4 tons/acre by the end of the study period. Under contemporary fire frequency, avoided wildfire benefits were comparatively small using both variable and constant risk models (maximum of 0.4 and 0.9 tons/acre respectively) (Table 11).

Table 12: Total avoided wildfire emissions benefit (GHGe/fireshed acre) under the Alt-SNAMP management scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP								
	Time (yrs)							
Frequency - Risk	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Restored (MFI 15)								
Variable	(2.29)	(8.48)	(17.63)	(27.02)	(27.98)	(23.77)	(16.17)	(4.02)
Constant	(9.00)	(9.31)	(10.27)	(11.12)	(9.55)	(7.40)	(4.83)	(1.18)
Intermediate (MFI 50)								
Variable	(0.21)	(0.87)	(2.13)	(4.01)	(5.22)	(5.61)	(4.77)	(1.45)
Constant	(2.96)	(3.07)	(3.38)	(3.66)	(3.14)	(2.44)	(1.59)	(0.39)
Contemporary (MFI 200)								
Variable	(0.01)	(0.06)	(0.14)	(0.26)	(0.35)	(0.39)	(0.35)	(0.11)
Constant	(0.76)	(0.79)	(0.87)	(0.94)	(0.81)	(0.63)	(0.41)	(0.10)

Table 13: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, restored frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	0.01	(0.65)	(1.21)	(1.72)	(1.48)	(2.56)	(1.92)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(2.27)	(8.49)	(16.97)	(25.82)	(26.26)	(22.29)	(13.61)	(2.10)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(2.29)**	**(8.48)**	**(17.63)**	**(27.02)**	**(27.98)**	**(23.77)**	**(16.17)**	**(4.02)**

Table 14: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, restored frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.08)	0.01	(0.38)	(0.50)	(0.59)	(0.46)	(0.77)	(0.56)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(8.92)	(9.32)	(9.89)	(10.62)	(8.96)	(6.94)	(4.06)	(0.62)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(9.00)**	**(9.31)**	**(10.27)**	**(11.12)**	**(9.55)**	**(7.40)**	**(4.83)**	**(1.18)**

Table 15: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, intermediate frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	0.00	(0.08)	(0.18)	(0.32)	(0.35)	(0.76)	(0.69)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.21)	(0.88)	(2.05)	(3.83)	(4.90)	(5.26)	(4.02)	(0.76)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.21)**	**(0.87)**	**(2.13)**	**(4.01)**	**(5.22)**	**(5.61)**	**(4.77)**	**(1.45)**

Table 16: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, intermediate frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.03)	0.00	(0.13)	(0.16)	(0.19)	(0.15)	(0.25)	(0.19)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(2.94)	(3.07)	(3.26)	(3.50)	(2.95)	(2.28)	(1.34)	(0.20)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(2.96)**	**(3.07)**	**(3.38)**	**(3.66)**	**(3.14)**	**(2.44)**	**(1.59)**	**(0.39)**

Table 17: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, contemporary frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	0.00	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.05)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.01)	(0.06)	(0.13)	(0.25)	(0.33)	(0.37)	(0.29)	(0.06)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.01)**	**(0.06)**	**(0.14)**	**(0.26)**	**(0.35)**	**(0.39)**	**(0.35)**	**(0.11)**

Table 18: Wildfire emissions accounting (GHGe/fireshed acre) under the Alt-SNAMP management scenario, contemporary frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.01)	0.00	(0.03)	(0.04)	(0.05)	(0.04)	(0.06)	(0.05)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.76)	(0.79)	(0.84)	(0.90)	(0.76)	(0.59)	(0.34)	(0.05)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.76)**	**(0.79)**	**(0.87)**	**(0.94)**	**(0.81)**	**(0.63)**	**(0.41)**	**(0.10)**

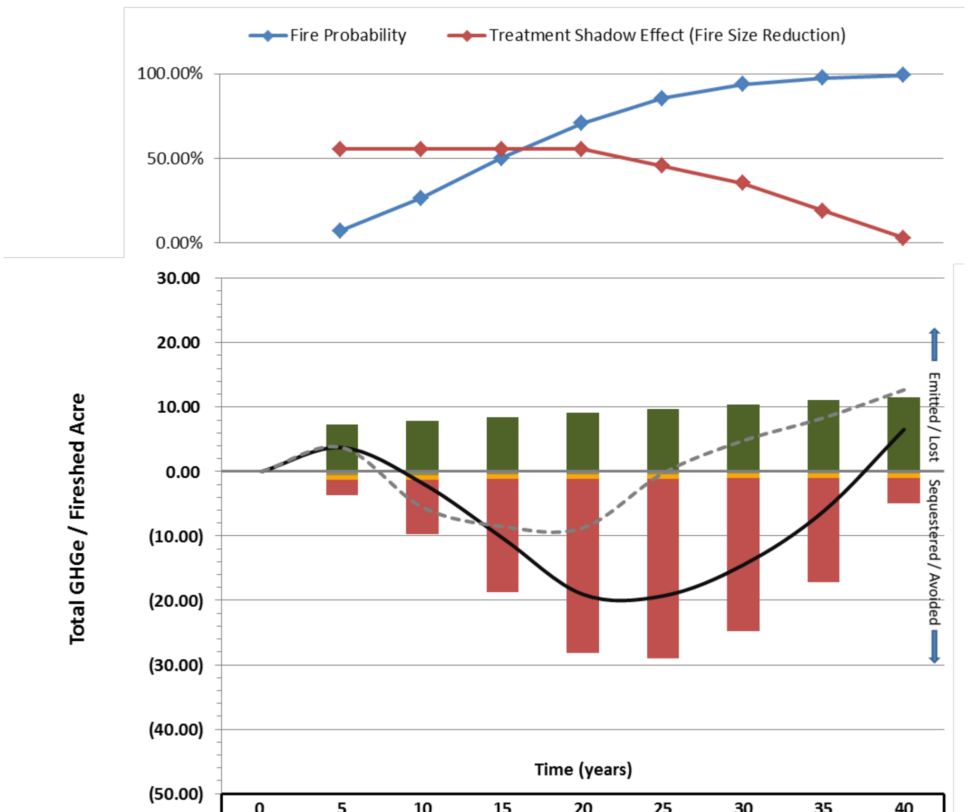
Net Benefits or Liabilities

Overall, the Alt-SNAMP scenario, under the most frequent fire regime (restored) and variable fire risk resulted in a net GHG loss (emission) at year 5, but due to increasing risk of fire, resulted in a net GHG benefit from year 10 through year 35. Year 40 saw net loss of GHGs again. Decreasing benefits from years 25 through 40 were largely a result of increasing fire size (reduced treatment shadow effect). This management scenario created a net GHG benefit when the probability of wildfire became high enough and the treatment shadow effect was still large. Benefits occurred from year 10 through year 35, with a peak of 19.3 tons/acre at year 25 (Table 12, Figure 20). Using the constant fire risk model, Alt-SNAMP provided net GHG benefits of approximately 3.0 tons/acre from year 5 through year 20, decreasing in year 25 and becoming a net liability (emission) after year 30. Loss of benefits coincided with reduced treatment shadow effect (fire size change) (Table 13, Figure 21).

Under intermediate and contemporary fire frequencies, both variable and constant risk models resulted in too little avoided wildfire emissions to create a net GHG benefit at any time step, even when coupled with wood product and biomass energy offsets. The relatively small risk of fire (0.0% - 2.7%) essentially nullified any benefit received that would have been received from avoided wildfire during the effective life of the treatments (Table 14, Figure 22, Table 15, Figure 23, Table 16, Figure 24, Table 17, Figure 25).

Table 19: Carbon accounting summary for the Alt-SNAMP management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	7.43%	26.56%	50.06%	70.90%	85.47%	93.78%	97.72%	99.28%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(2.29)	(8.48)	(17.63)	(27.02)	(27.98)	(23.77)	(16.17)	(4.02)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	3.73	(1.79)	(10.30)	(19.05)	(19.29)	(14.49)	(6.14)	6.54



	0	5	10	15	20	25	30	35	40
Wildfire	-	(2.29)	(8.48)	(17.63)	(27.02)	(27.98)	(23.77)	(16.17)	(4.02)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	3.73	(1.79)	(10.30)	(19.05)	(19.29)	(14.49)	(6.14)	6.54
Net	-	3.73	(5.52)	(8.52)	(8.74)	(0.25)	4.81	8.34	12.68

Figure 20: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "restored" fire frequency and variable risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 20: Carbon accounting summary for the Alt-SNAMP management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

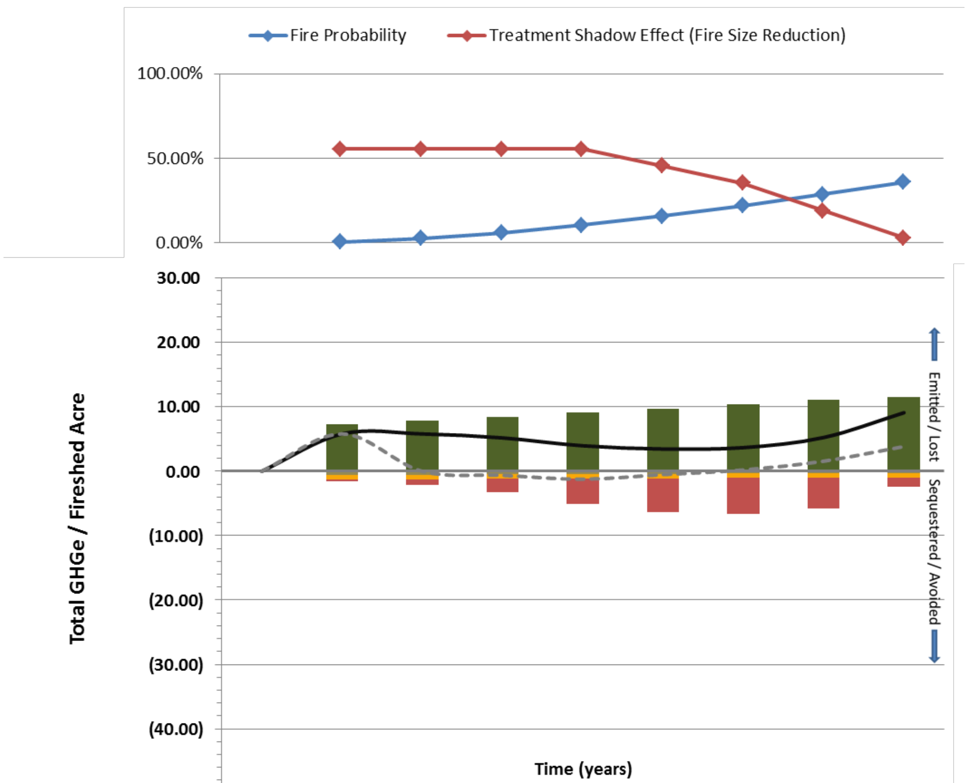
ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(9.00)	(9.31)	(10.27)	(11.12)	(9.55)	(7.40)	(4.83)	(1.18)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	(2.98)	(2.63)	(2.95)	(3.14)	(0.87)	1.89	5.20	9.37

	0	5	10	15	20	25	30	35	40
Wildfire	-	(9.00)	(9.31)	(10.27)	(11.12)	(9.55)	(7.40)	(4.83)	(1.18)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	(2.98)	(2.63)	(2.95)	(3.14)	(0.87)	1.89	5.20	9.37
Net	-	(2.98)	0.35	(0.32)	(0.19)	2.28	2.76	3.31	4.17

Figure 21: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "restored" fire frequency and constant risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 21: Carbon accounting summary for the Alt-SNAMP management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	0.69%	2.74%	6.06%	10.52%	15.94%	22.12%	28.84%	35.88%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.21)	(0.87)	(2.13)	(4.01)	(5.22)	(5.61)	(4.77)	(1.45)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.81**	**5.81**	**5.19**	**3.97**	**3.46**	**3.68**	**5.26**	**9.10**



	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.21)	(0.87)	(2.13)	(4.01)	(5.22)	(5.61)	(4.77)	(1.45)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	5.81	5.81	5.19	3.97	3.46	3.68	5.26	9.10
Net	-	5.81	0.01	(0.62)	(1.22)	(0.50)	0.21	1.58	3.85

Figure 22: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "intermediate" fire frequency and variable risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 22: Carbon accounting summary for the Alt-SNAMP management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

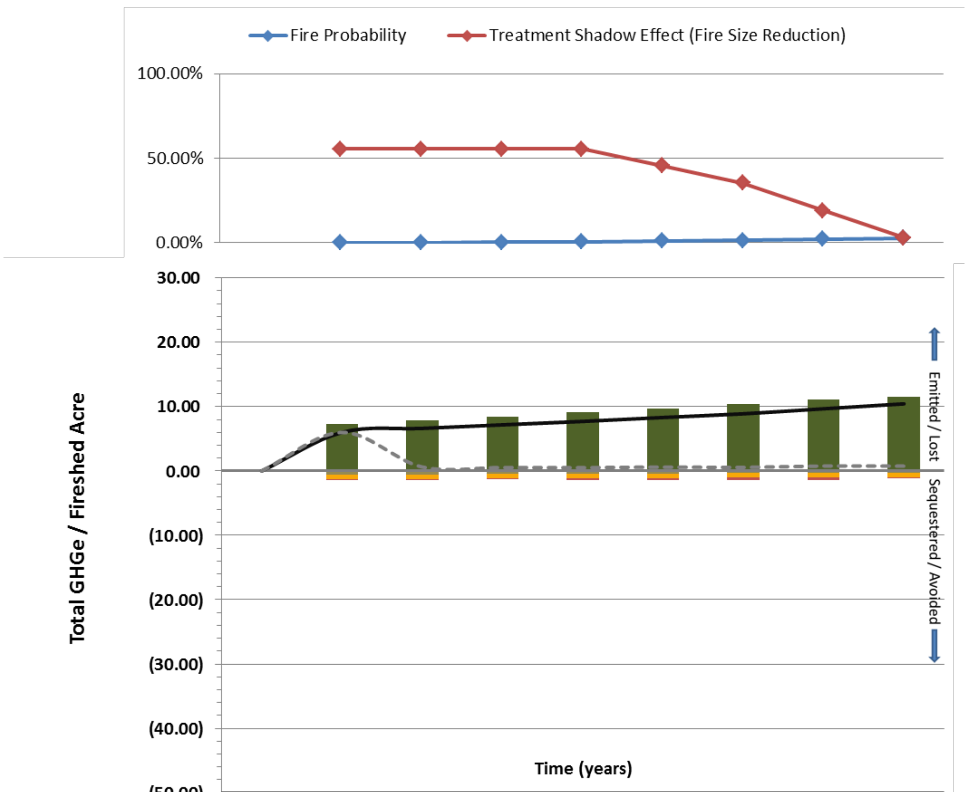
ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(2.96)	(3.07)	(3.38)	(3.66)	(3.14)	(2.44)	(1.59)	(0.39)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**3.06**	**3.62**	**3.94**	**4.31**	**5.54**	**6.85**	**8.44**	**10.17**

	0	5	10	15	20	25	30	35	40
Wildfire	-	(2.96)	(3.07)	(3.38)	(3.66)	(3.14)	(2.44)	(1.59)	(0.39)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	3.06	3.62	3.94	4.31	5.54	6.85	8.44	10.17
Net	-	3.06	0.56	0.32	0.37	1.22	1.31	1.59	1.73

Figure 23: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "intermediate" fire frequency and variable risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 23: Carbon accounting summary for the Alt-SNAMP management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	0.04%	0.17%	0.39%	0.69%	1.08%	1.55%	2.10%	2.74%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.01)	(0.06)	(0.14)	(0.26)	(0.35)	(0.39)	(0.35)	(0.11)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	6.01	6.63	7.19	7.71	8.33	8.89	9.68	10.44

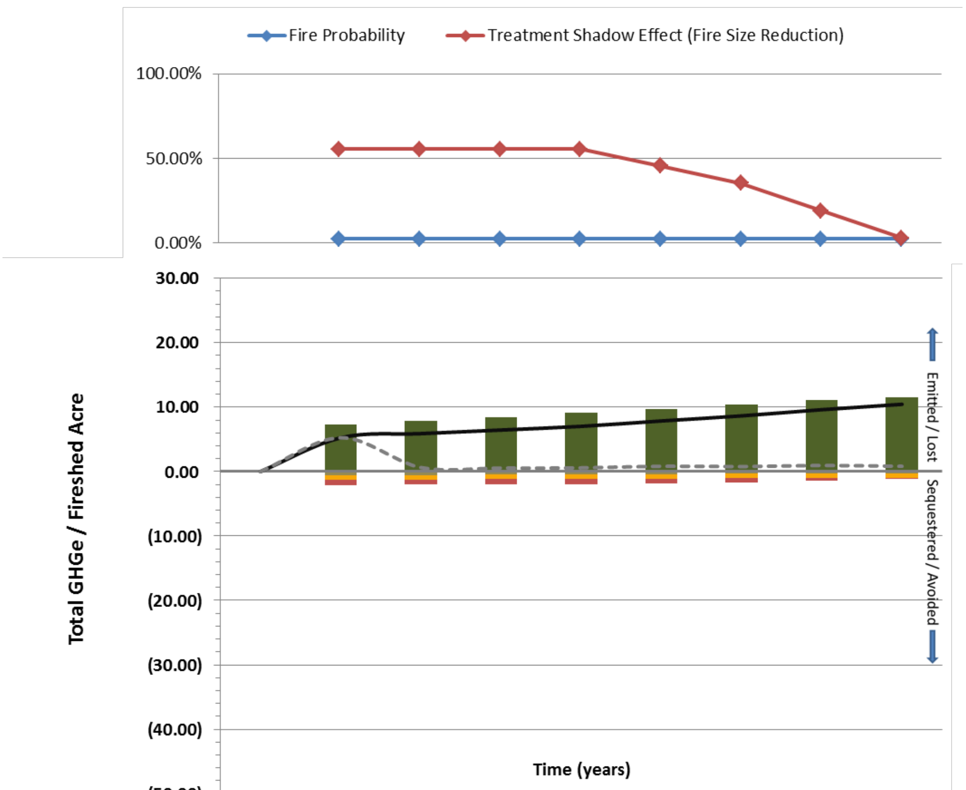


	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.01)	(0.06)	(0.14)	(0.26)	(0.35)	(0.39)	(0.35)	(0.11)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	6.01	6.63	7.19	7.71	8.33	8.89	9.68	10.44
Net	-	6.01	0.63	0.55	0.53	0.62	0.57	0.79	0.76

Figure 24: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "contemporary" fire frequency and variable risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 24: Carbon accounting summary for the Alt-SNAMP management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Total Wood Product LCA Benefit (GHG / ac)	-	(1.32)	(1.22)	(1.16)	(1.11)	(1.07)	(1.04)	(1.02)	(0.99)
Probability of Fire	-	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.76)	(0.79)	(0.87)	(0.94)	(0.81)	(0.63)	(0.41)	(0.10)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	**5.26**	**5.90**	**6.45**	**7.03**	**7.87**	**8.66**	**9.62**	**10.46**



	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.76)	(0.79)	(0.87)	(0.94)	(0.81)	(0.63)	(0.41)	(0.10)
Biomass Energy	-	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)	(0.68)
Wood Products	-	(0.63)	(0.53)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Forest Carbon	-	7.34	7.90	8.48	9.09	9.75	10.33	11.05	11.55
Accumulated	-	5.26	5.90	6.45	7.03	7.87	8.66	9.62	10.46
Net	-	5.26	0.64	0.55	0.58	0.84	0.79	0.96	0.83

Figure 25: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Alt-SNAMP management scenario, with "contemporary" fire frequency and variable risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Management Scenario: USFS-Standard

Forest Carbon

Similar to the Alt-SNAMP scenario, forest growth modeling under the USFS-Standard scenario also showed a growing, but slightly larger, deficit of sequestered GHGs when compared to the baseline (Base-BAU) over the study period. The deficit of stored GHGs between the USFS-Standard and Base-BAU scenarios grew from 8.5 tons/acre 5 years post treatment, to 16.9 tons/acre 40 years post treatment, although this deficit remained roughly proportional to the total volume of stored forest carbon (about 4% of baseline) (Table 18). These amounts are considered as net GHG losses, but can be offset by GHGs that become stored in wood products (durable and waste), biomass used in energy production, and changes in expected wildfire emissions.

Table 25: Forest carbon stock and growth for the USFS-Standard scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**

Wood Products and Biomass Energy

The USFS–Standard scenario resulted in approximately 2.8 and 5.2 tons/acre of GHG removed from the forest as merchantable and non-merchantable wood, respectively. Accounting for biomass utilization, mill efficiency and wood product decay in the LCA, wood removal resulted in stored or offset GHGs of approximately 2.8 tons/acre after 5 years, declining to 2.0 tons/acre after 40 years though still greater than the Alt-SNAMP scenario (Table 19). Offsets from these framework elements were never enough to negate the loss of carbon resulting from removal (treatment) over the course of the study period.

Table 26: Wood product life cycle analysis results for the USFS-Standard scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**

Wildfire

Direct wildfire emissions were reduced after treatment (year 5) by 3.3 tons/acre. Reductions increased through year 40 at 9.0 tons/acre. The USFS-Standard treatments reduced average fire size in the fireshed by 68% at year 5, with this reduction diminishing to 14% by year 40.

Accounting for direct wildfire emissions, treatment shadow effect, and fire risk, the USFS-Standard scenario with restored fire frequency (variable risk) resulted in a net GHG benefit from avoided wildfire of 3.0 tons/acre at 5 years post treatment, increasing to 32.3 tons/acre 25 years post treatment, then decreasing to 18.9 tons/acre at 40 years. Using the constant fire risk model, the USFS-Standard scenario under restored fire frequency provided a net benefit in avoided wildfire emissions of 11.9 tons/acre at year 5, increasing to 12.8 tons/acre at year 15, then decreasing to 5.5 tons per acre at year 40. Under an intermediate fire frequency scenario (variable risk), USFS Standard provided net avoided wildfire benefits of 0.3 tons per acre at year 5, increasing to 7.9 tons/acre at year 35, then decreasing to 6.8 tons per acre by the end of the study period. The constant risk model for this frequency showed net avoided wildfire benefits of about 4 tons/acre for the first 25 years, then decreasing to 1.8 tons/acre by the end of the study period. Under contemporary fire frequency, avoided wildfire benefits were comparatively small using both variable and constant risk models (maximum of 0.6 and 1.1 tons/acre respectively) (Table 20).

Table 27: Total wildfire emissions benefit (GHGe/fireshed acre) under the USFS-Standard management scenario. (Negative) values indicate avoided emissions.

USFS - STANDARD								
	Time (yrs)							
Frequency - Risk	5	10	15	20	25	30	35	40
Restored (MFI 15)								
Variable	(3.02)	(10.98)	(21.93)	(29.89)	(32.39)	(29.85)	(26.67)	(18.87)
Constant	(11.88)	(12.06)	(12.78)	(12.30)	(11.06)	(9.29)	(7.96)	(5.54)
Intermediate (MFI 50)								
Variable	(0.28)	(1.13)	(2.65)	(4.43)	(6.04)	(7.04)	(7.87)	(6.82)
Constant	(3.91)	(3.97)	(4.21)	(4.05)	(3.64)	(3.06)	(2.62)	(1.83)
Contemporary (MFI 200)								
Variable	(0.02)	(0.07)	(0.17)	(0.29)	(0.41)	(0.49)	(0.57)	(0.52)
Constant	(1.01)	(1.02)	(1.08)	(1.04)	(0.94)	(0.79)	(0.68)	(0.47)

Table 28: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, restored frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.25)	(1.06)	(2.71)	(4.37)	(5.65)	(6.09)	(8.34)	(8.97)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(2.77)	(9.91)	(19.21)	(25.52)	(26.74)	(23.76)	(18.32)	(9.89)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.02)**	**(10.98)**	**(21.93)**	**(29.89)**	**(32.39)**	**(29.85)**	**(26.67)**	**(18.87)**

Table 29: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, restored frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.98)	(1.17)	(1.58)	(1.80)	(1.93)	(1.90)	(2.49)	(2.64)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(10.90)	(10.89)	(11.20)	(10.50)	(9.13)	(7.39)	(5.47)	(2.91)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(11.88)**	**(12.06)**	**(12.78)**	**(12.30)**	**(11.06)**	**(9.29)**	**(7.96)**	**(5.54)**

Table 30: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, intermediate frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.11)	(0.33)	(0.65)	(1.05)	(1.44)	(2.46)	(3.24)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.26)	(1.02)	(2.33)	(3.78)	(4.99)	(5.60)	(5.41)	(3.58)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.28)**	**(1.13)**	**(2.65)**	**(4.43)**	**(6.04)**	**(7.04)**	**(7.87)**	**(6.82)**

Table 31: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, intermediate frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.32)	(0.38)	(0.52)	(0.59)	(0.63)	(0.62)	(0.82)	(0.87)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(3.59)	(3.59)	(3.69)	(3.46)	(3.01)	(2.43)	(1.80)	(0.96)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.91)**	**(3.97)**	**(4.21)**	**(4.05)**	**(3.64)**	**(3.06)**	**(2.62)**	**(1.83)**

Table 32: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, contemporary frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	(0.01)	(0.02)	(0.04)	(0.07)	(0.10)	(0.18)	(0.25)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.06)	(0.15)	(0.25)	(0.34)	(0.39)	(0.39)	(0.27)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.02)**	**(0.07)**	**(0.17)**	**(0.29)**	**(0.41)**	**(0.49)**	**(0.57)**	**(0.52)**

Table 33: Wildfire emissions accounting (GHGe/fireshed acre) under the USFS-Standard management scenario, contemporary frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.08)	(0.10)	(0.13)	(0.15)	(0.16)	(0.16)	(0.21)	(0.22)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.92)	(0.92)	(0.95)	(0.89)	(0.77)	(0.63)	(0.46)	(0.25)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(1.01)**	**(1.02)**	**(1.08)**	**(1.04)**	**(0.94)**	**(0.79)**	**(0.68)**	**(0.47)**

Net Benefits or Liabilities

Overall, the USFS-Standard scenario, under the most frequent fire regime (restored) and variable fire risk resulted in a net GHG loss (emission) at year 5 of 2.7 tons/acre, but due to increasing risk of fire, resulted in a net GHG benefit from year 10 through the end of the study period. Net benefits peaked in year 25 at 21.0 tons/acre. Decreasing benefits from years 30 through 40 were largely a result of increasing fire size (reduced treatment shadow effect). This management scenario created a net GHG benefit when the probability of wildfire became high enough. This benefit was reduced as treatment effectiveness decreased, but was was still a net positive after 40 years (Table 21, Figure 26). Under restored fire frequency and constant fire risk, USFS-Standard provided net GHG benefits from year 5 (6.2 tons/acre) through year 20 (2.3 tons/acre), then becoming a net liability (emission). Decreasing benefits coincided with decreasing treatment shadow effect (change in fire size) (Table 22, Figure 27).

Under intermediate and contemporary fire frequencies, both variable and constant risk models resulted in too little avoided wildfire emissions to create a net GHG benefit at any time step, even when coupled with wood product and biomass energy offsets. The relatively small risk of fire (0.0% - 2.7%) essentially nullified any benefit received that would have been received from avoided wildfire during the effective life of the treatments (Table 23, Figure 28, Table 24, Figure 29, Table 25, Figure 30, Table 26, Figure 31).

Table 34: Carbon accounting summary for the USFS-Standard management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

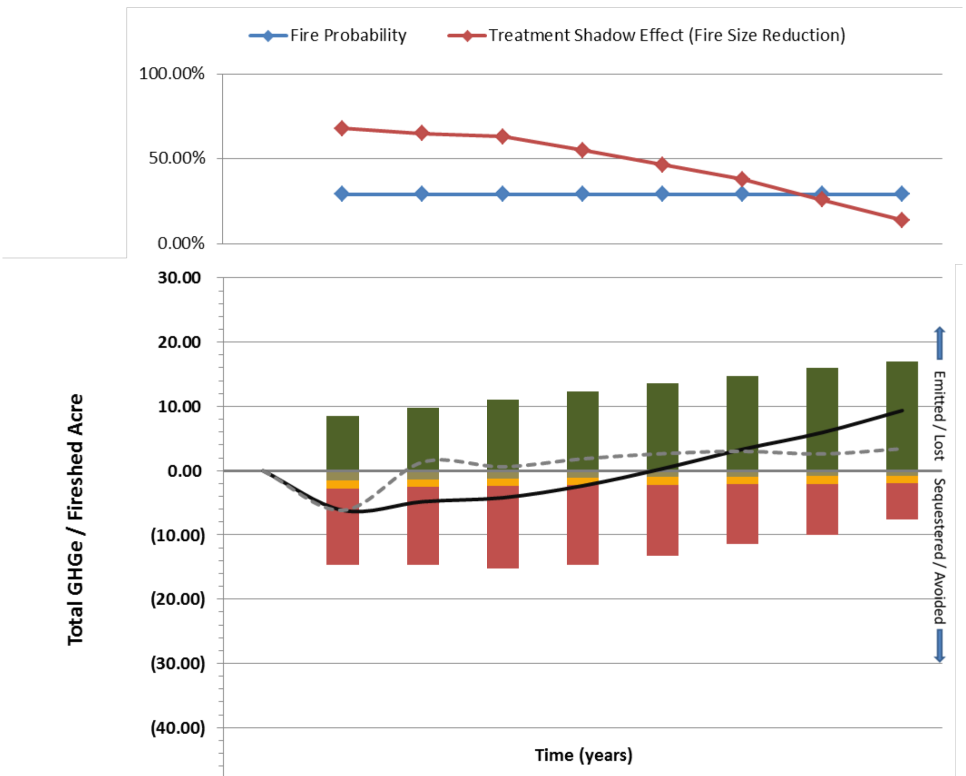
USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	7.43%	26.56%	50.06%	70.90%	85.47%	93.78%	97.72%	99.28%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(3.02)	(10.98)	(21.93)	(29.89)	(32.39)	(29.85)	(26.67)	(18.87)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	2.70	(3.73)	(13.35)	(19.93)	(21.02)	(17.23)	(12.75)	(3.95)

	0	5	10	15	20	25	30	35	40
Wildfire	-	(3.02)	(10.98)	(21.93)	(29.89)	(32.39)	(29.85)	(26.67)	(18.87)
Biomass Energy	-	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Wood Products	-	(1.58)	(1.33)	(1.18)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Forest Carbon	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Accumulated	-	2.70	(3.73)	(13.35)	(19.93)	(21.02)	(17.23)	(12.75)	(3.95)
Net	-	2.70	(6.43)	(9.62)	(6.58)	(1.09)	3.79	4.48	8.80

Figure 26: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "restored" fire frequency and variable risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 35: Carbon accounting summary for the USFS-Standard management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(11.88)	(12.06)	(12.78)	(12.30)	(11.06)	(9.29)	(7.96)	(5.54)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	(6.16)	(4.82)	(4.20)	(2.34)	0.31	3.34	5.95	9.37

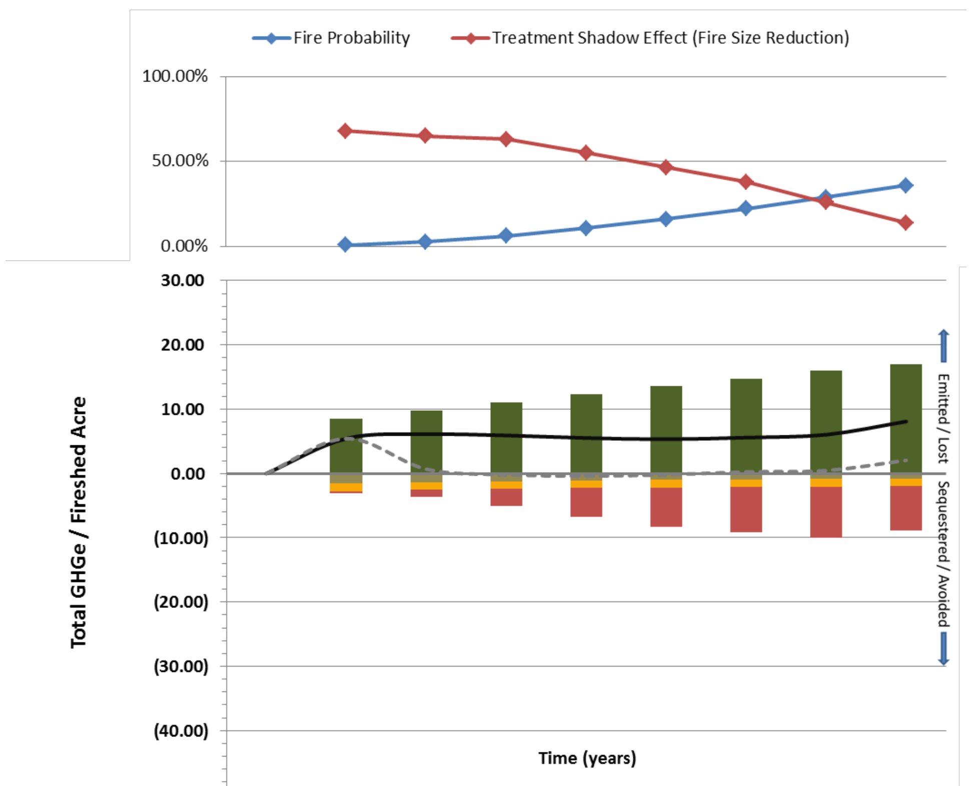


	0	5	10	15	20	25	30	35	40
Wildfire	-	(11.88)	(12.06)	(12.78)	(12.30)	(11.06)	(9.29)	(7.96)	(5.54)
Biomass Energy	-	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Wood Products	-	(1.58)	(1.33)	(1.18)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Forest Carbon	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Accumulated	-	(6.16)	(4.82)	(4.20)	(2.34)	0.31	3.34	5.95	9.37
Net	-	(6.16)	1.34	0.61	1.86	2.66	3.02	2.61	3.42

Figure 27: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "restored" fire frequency and constant risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 36: Carbon accounting summary for the USFS-Standard management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	0.69%	2.74%	6.06%	10.52%	15.94%	22.12%	28.84%	35.88%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.28)	(1.13)	(2.65)	(4.43)	(6.04)	(7.04)	(7.87)	(6.82)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	5.44	6.11	5.92	5.52	5.33	5.58	6.04	8.09

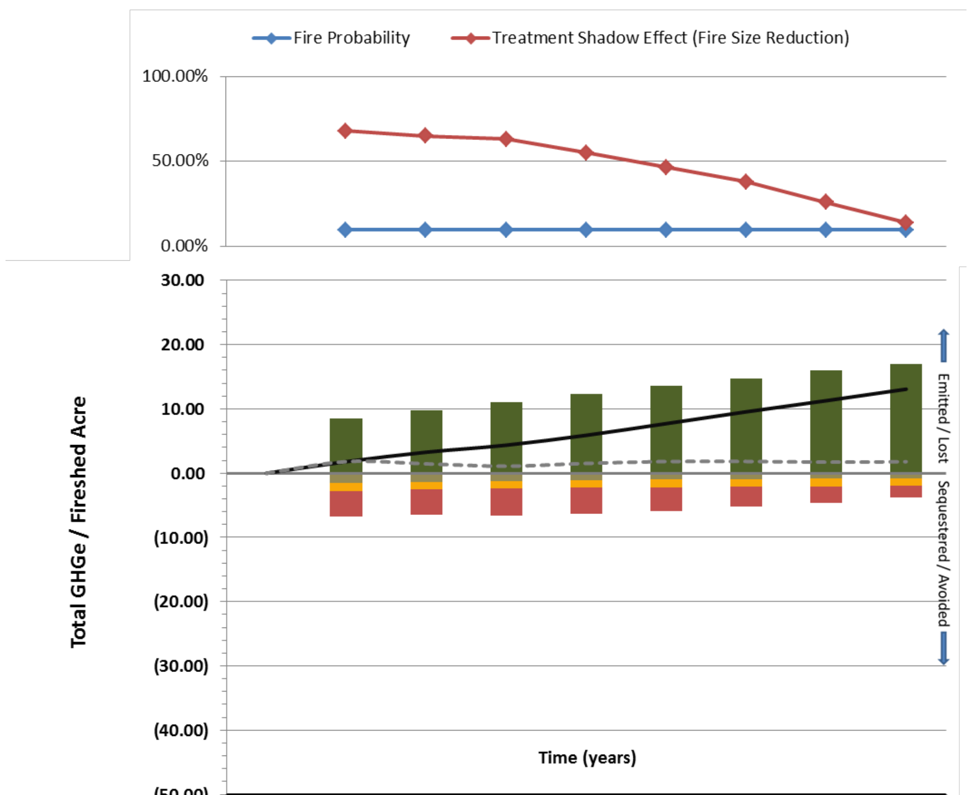


	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.28)	(1.13)	(2.65)	(4.43)	(6.04)	(7.04)	(7.87)	(6.82)
Biomass Energy	-	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Wood Products	-	(1.58)	(1.33)	(1.18)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Forest Carbon	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Accumulated	-	5.44	6.11	5.92	5.52	5.33	5.58	6.04	8.09
Net	-	5.44	0.68	(0.19)	(0.40)	(0.19)	0.25	0.46	2.05

Figure 28: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "intermediate" fire frequency and variable risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 37: Carbon accounting summary for the USFS-Standard management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(3.91)	(3.97)	(4.21)	(4.05)	(3.64)	(3.06)	(2.62)	(1.83)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**1.81**	**3.27**	**4.37**	**5.90**	**7.73**	**9.57**	**11.29**	**13.09**



	0	5	10	15	20	25	30	35	40
Wildfire	-	(3.91)	(3.97)	(4.21)	(4.05)	(3.64)	(3.06)	(2.62)	(1.83)
Biomass Energy	-	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Wood Products	-	(1.58)	(1.33)	(1.18)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Forest Carbon	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Accumulated	-	1.81	3.27	4.37	5.90	7.73	9.57	11.29	13.09
Net	-	1.81	1.47	1.09	1.54	1.82	1.84	1.72	1.80

Figure 29: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "intermediate" fire frequency and constant risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 38: Carbon accounting summary for the USFS-Standard management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	0.04%	0.17%	0.39%	0.69%	1.08%	1.55%	2.10%	2.74%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.02)	(0.07)	(0.17)	(0.29)	(0.41)	(0.49)	(0.57)	(0.52)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.70**	**7.17**	**8.40**	**9.66**	**10.96**	**12.13**	**13.34**	**14.39**

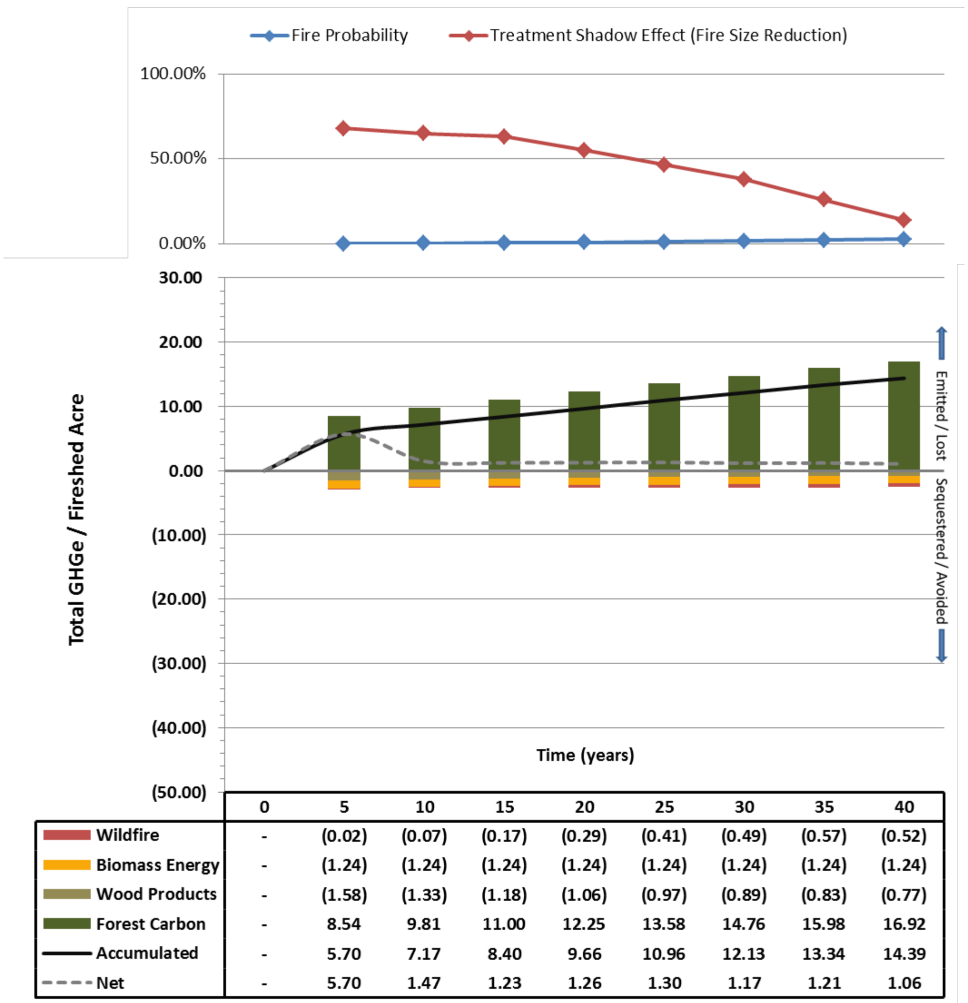
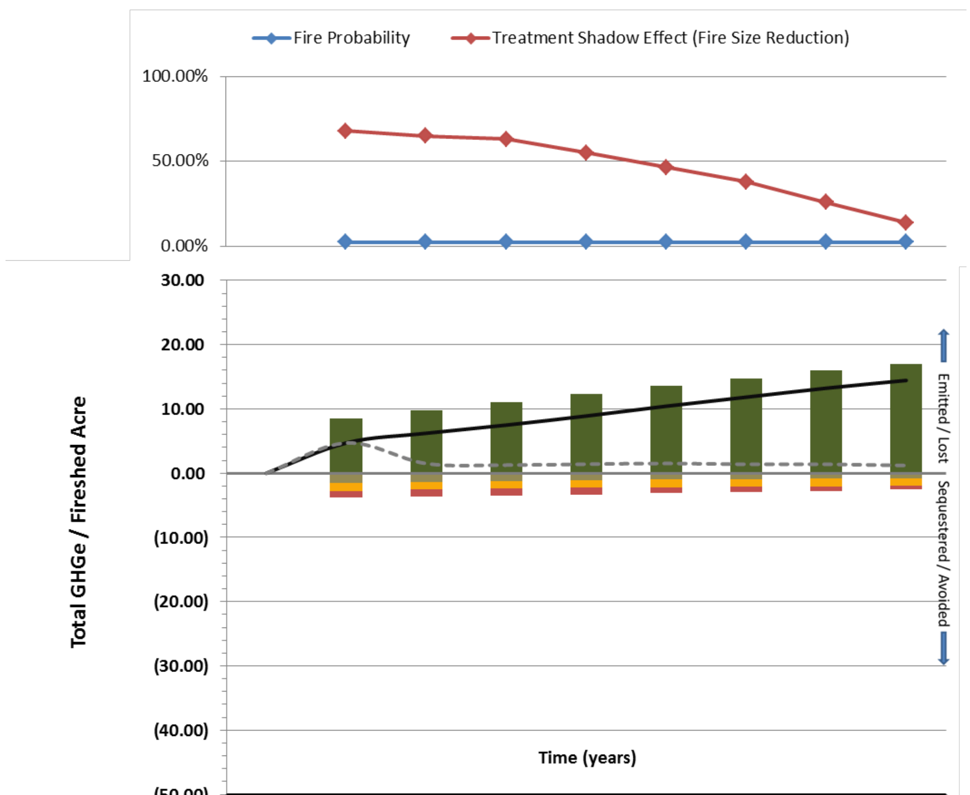


Figure 30: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "contemporary" fire frequency and variable risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 39: Carbon accounting summary for the USFS-Standard management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Total Wood Product LCA Benefit (GHG / ac)	-	(2.82)	(2.57)	(2.42)	(2.30)	(2.21)	(2.13)	(2.07)	(2.01)
Probability of Fire	-	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(1.01)	(1.02)	(1.08)	(1.04)	(0.94)	(0.79)	(0.68)	(0.47)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**4.71**	**6.22**	**7.49**	**8.91**	**10.43**	**11.84**	**13.24**	**14.44**



	0	5	10	15	20	25	30	35	40
Wildfire	-	(1.01)	(1.02)	(1.08)	(1.04)	(0.94)	(0.79)	(0.68)	(0.47)
Biomass Energy	-	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Wood Products	-	(1.58)	(1.33)	(1.18)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Forest Carbon	-	8.54	9.81	11.00	12.25	13.58	14.76	15.98	16.92
Accumulated	-	4.71	6.22	7.49	8.91	10.43	11.84	13.24	14.44
Net	-	4.71	1.51	1.27	1.42	1.52	1.40	1.40	1.21

Figure 31: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the USFS-Standard management scenario, with "contemporary" fire frequency and constant risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Management Scenario: Private-Harvest

Forest Carbon

The Private-Harvest management scenario was designed to remove a much larger volume of wood/biomass from the forest, primarily in the form of larger overstory trees. Starting with this much larger deficit in residual biomass to grow, forest growth modeling under the Private-Harvest scenario showed a significantly greater deficit of sequestered GHGs vs. the baseline (Base-BAU) over the study period than did the Alt-SNAMP or USFS-Standard scenarios. As the baseline and treated forests grew, this deficit grew from 54.8 tons/acre (5 years post treatment) to 71.3 tons/acre (40 years post treatment). As a proportion of total forest carbon, however, the deficit became smaller over the course of the study period, shrinking from 22% to 17% of baseline volume, suggesting that the treated forest was sequestering carbon at a faster rate than the baseline (Table 27). These deficit amounts are considered as net GHG losses from the forest (emissions), but can be offset by GHGs that become stored in wood products (durable and waste), biomass used in energy production, and changes in expected wildfire emissions.

Table 40: Forest carbon stock and growth for the Private-Harvest scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**

Wood Products and Biomass Energy

The Private-Harvest scenario resulted in approximately 29.0 and 7.8 tons/acre of GHG removed from the forest as merchantable and non-merchantable wood, respectively. Accounting for biomass utilization, mill efficiency and wood product decay in the LCA, wood removal resulted in stored or offset GHGs of approximately 20.5 tons/acre after 5 years, declining to 12.1 tons/acre after 40 years, though still much greater than either the Alt-SNAMP scenario or USFS-Standard scenario (Table 28). Offsets from these framework elements were never enough to negate the loss of carbon resulting from removal (treatment) over the course of the study period.

Table 41: Wood product life cycle analysis results for the Private-Harvest scenario. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**

Wildfire

Direct wildfire emissions were reduced after treatment (year 5) by 5.9 tons/acre. Reductions increased through year 40 at 18.6 tons/acre. The Private-Harvest treatments reduced average fire size in the fireshed by 85% at year 5, with this reduction diminishing to 46% by year 40.

Accounting for direct wildfire emissions, treatment shadow effect, and fire risk, the Private-Harvest scenario with restored fire frequency (variable risk) resulted in a net GHG benefit from avoided wildfire of 3.9 tons/acre at 5 years post treatment, increasing to 53.9 tons/acre 35 years post treatment, then decreasing slightly to 51.0 tons/acre at 40 years. Using the constant fire risk model, the Private-Harvest scenario under restored fire frequency provided a net benefit in avoided wildfire emissions at each time step that varied between 13.9 and 16.1 tons/acre. Under an intermediate fire frequency scenario (variable risk), the Private-Harvest scenario provided net avoided wildfire benefits of 0.4 tons per acre at year 5, increasing to 18.4 tons/acre at year 40. The constant risk model for this frequency showed net avoided wildfire benefits of about 5 tons/acre for the entire study period. Under contemporary fire frequency, avoided wildfire benefits were comparatively small using both variable and constant risk models (maximum of 1.4 and 1.3 tons/acre respectively) (Table 29).

Table 42: Total wildfire emissions benefit (GHGe/fireshed acre) under the Private-Harvest management scenario. (Negative) values indicate avoided emissions.

PRIVATE - HARVEST								
	Time (yrs)							
Frequency - Risk	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Restored (MFI 15)								
Variable	(3.90)	(12.65)	(25.59)	(39.03)	(47.10)	(48.98)	(53.91)	(51.02)
Constant	(15.34)	(13.90)	(14.91)	(16.06)	(16.08)	(15.24)	(16.10)	(14.99)
Intermediate (MFI 50)								
Variable	(0.36)	(1.30)	(3.10)	(5.79)	(8.78)	(11.55)	(15.91)	(18.44)
Constant	(5.05)	(4.58)	(4.91)	(5.29)	(5.29)	(5.02)	(5.30)	(4.94)
Contemporary (MFI 200)								
Variable	(0.02)	(0.08)	(0.20)	(0.38)	(0.59)	(0.81)	(1.16)	(1.41)
Constant	(1.30)	(1.18)	(1.27)	(1.36)	(1.36)	(1.29)	(1.37)	(1.27)

Table 43: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, restored frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.44)	(1.52)	(4.24)	(7.34)	(10.66)	(12.43)	(17.09)	(18.47)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(3.47)	(11.13)	(21.35)	(31.69)	(36.44)	(36.54)	(36.82)	(32.55)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.90)**	**(12.65)**	**(25.59)**	**(39.03)**	**(47.10)**	**(48.98)**	**(53.91)**	**(51.02)**

Table 44: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, restored frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(1.71)	(1.67)	(2.47)	(3.02)	(3.64)	(3.87)	(5.10)	(5.43)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(13.63)	(12.23)	(12.44)	(13.04)	(12.44)	(11.37)	(10.99)	(9.56)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(15.34)**	**(13.90)**	**(14.91)**	**(16.06)**	**(16.08)**	**(15.24)**	**(16.10)**	**(14.99)**

Table 45: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, intermediate frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.04)	(0.16)	(0.51)	(1.09)	(1.99)	(2.93)	(5.04)	(6.67)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.32)	(1.15)	(2.58)	(4.70)	(6.80)	(8.62)	(10.87)	(11.76)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.36)**	**(1.30)**	**(3.10)**	**(5.79)**	**(8.78)**	**(11.55)**	**(15.91)**	**(18.44)**

Table 46: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, intermediate frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.56)	(0.55)	(0.81)	(0.99)	(1.20)	(1.27)	(1.68)	(1.79)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(4.49)	(4.03)	(4.10)	(4.29)	(4.10)	(3.74)	(3.62)	(3.15)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(5.05)**	**(4.58)**	**(4.91)**	**(5.29)**	**(5.29)**	**(5.02)**	**(5.30)**	**(4.94)**

Table 47: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, contemporary frequency, and variable risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	(0.01)	(0.03)	(0.07)	(0.13)	(0.21)	(0.37)	(0.51)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.07)	(0.17)	(0.31)	(0.46)	(0.60)	(0.79)	(0.90)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.02)**	**(0.08)**	**(0.20)**	**(0.38)**	**(0.59)**	**(0.81)**	**(1.16)**	**(1.41)**

Table 48: Wildfire emissions accounting (GHGe/fireshed acre) under the Private-Harvest management scenario, contemporary frequency, and constant risk model. Values (metric tons GHGe) are in terms of GHG emissions, where positive values are emissions or equivalent carbon loss, and (negative) values are carbon sequestered or emissions avoided.

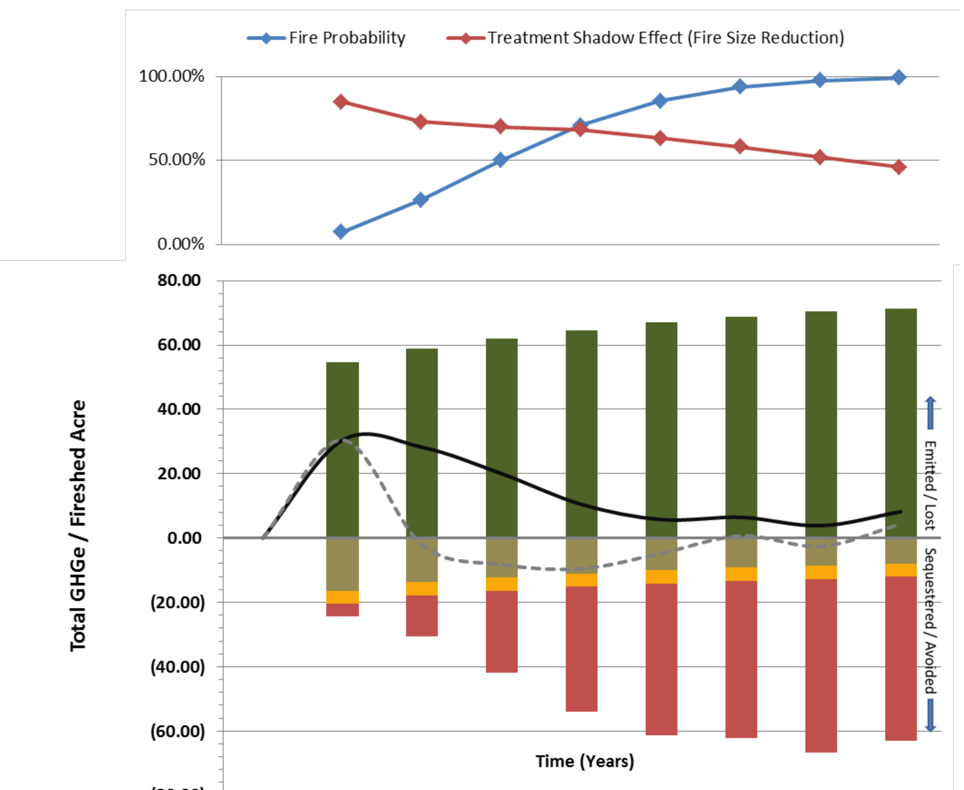
PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.15)	(0.14)	(0.21)	(0.26)	(0.31)	(0.33)	(0.43)	(0.46)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(1.16)	(1.04)	(1.06)	(1.11)	(1.06)	(0.96)	(0.93)	(0.81)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(1.30)**	**(1.18)**	**(1.27)**	**(1.36)**	**(1.36)**	**(1.29)**	**(1.37)**	**(1.27)**

Net Benefits or Liabilities

Overall, the Private-Harvest scenario, under the most frequent fire regime (restored) and variable fire risk resulted in net GHG losses (emissions) for the entire study period. However, as fire risk increased, treatment shadow effect decreased, and the forest carbon deficit rate slowed, the net liability shrank from a peak of 30.4 tons/acre at year 5 to 3.85 tons/acre at year 35 (Table 30, Figure 32). Using a constant fire risk model, however liabilities increased at each time step from 19.0 to 44.2 tons/acre over the 40 years (Table 31, Figure 33). The decreased risk of fire under the intermediate and contemporary frequency scenarios (using both variable and constant risk) only decreased avoided wildfire emissions and increased liabilities (Table 32, Figure 34, Table 33, Figure 35, Table 34, Figure 36, Table 35, Figure 37).

Table 49: Carbon accounting summary for the Private-Harvest management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	7.43%	26.56%	50.06%	70.90%	85.47%	93.78%	97.72%	99.28%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(3.90)	(12.65)	(25.59)	(39.03)	(47.10)	(48.98)	(53.91)	(51.02)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	30.43	28.21	19.96	10.43	5.73	6.45	3.85	8.22

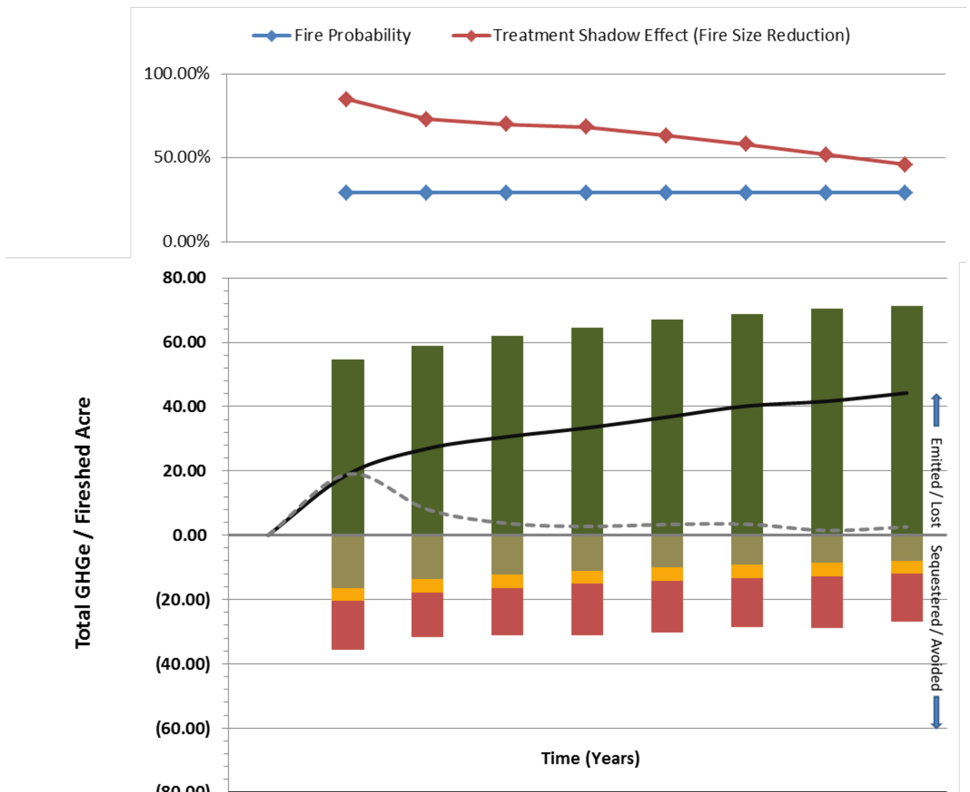


	0	5	10	15	20	25	30	35	40
Wildfire	-	(3.90)	(12.65)	(25.59)	(39.03)	(47.10)	(48.98)	(53.91)	(51.02)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	30.43	28.21	19.96	10.43	5.73	6.45	3.85	8.22
Net	-	30.43	(2.21)	(8.25)	(9.53)	(4.70)	0.72	(2.60)	4.37

Figure 32: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "restored" fire frequency and variable risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 50: Carbon accounting summary for the Private-Harvest management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%	29.18%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(15.34)	(13.90)	(14.91)	(16.06)	(16.08)	(15.24)	(16.10)	(14.99)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**18.99**	**26.97**	**30.64**	**33.40**	**36.75**	**40.19**	**41.66**	**44.24**

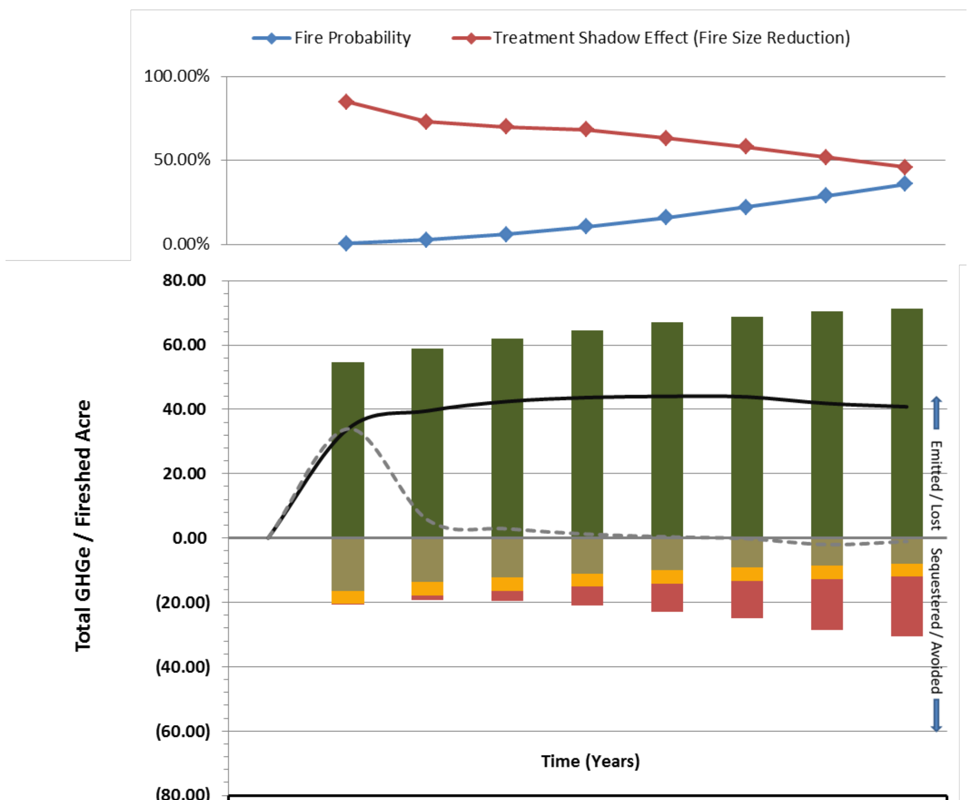


	0	5	10	15	20	25	30	35	40
Wildfire	-	(15.34)	(13.90)	(14.91)	(16.06)	(16.08)	(15.24)	(16.10)	(14.99)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	18.99	26.97	30.64	33.40	36.75	40.19	41.66	44.24
Net	-	18.99	7.97	3.67	2.76	3.35	3.43	1.47	2.58

Figure 33: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "restored" fire frequency and constant risk (MFI 15 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 51: Carbon accounting summary for the Private-Harvest management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	0.69%	2.74%	6.06%	10.52%	15.94%	22.12%	28.84%	35.88%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.36)	(1.30)	(3.10)	(5.79)	(8.78)	(11.55)	(15.91)	(18.44)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	33.97	39.56	42.45	43.67	44.05	43.87	41.84	40.79

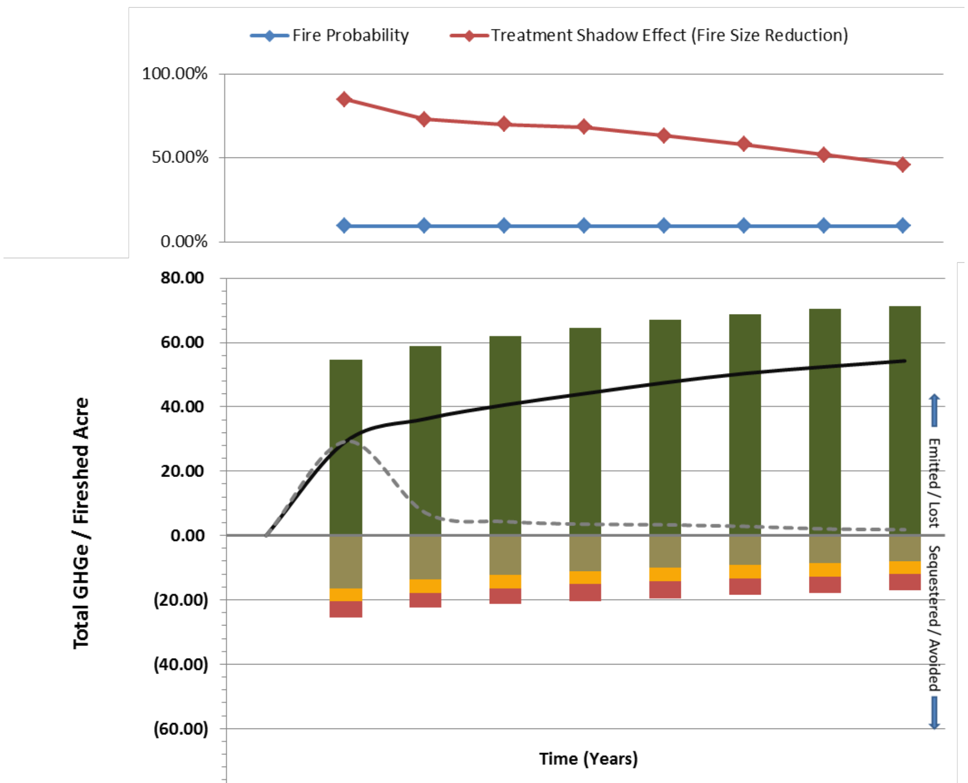


	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.36)	(1.30)	(3.10)	(5.79)	(8.78)	(11.55)	(15.91)	(18.44)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	33.97	39.56	42.45	43.67	44.05	43.87	41.84	40.79
Net	-	33.97	5.59	2.89	1.22	0.38	(0.18)	(2.03)	(1.05)

Figure 34: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "intermediate" fire frequency and variable risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 52: Carbon accounting summary for the Private-Harvest management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%	9.61%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(5.05)	(4.58)	(4.91)	(5.29)	(5.29)	(5.02)	(5.30)	(4.94)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**29.28**	**36.29**	**40.64**	**44.17**	**47.54**	**50.41**	**52.46**	**54.29**

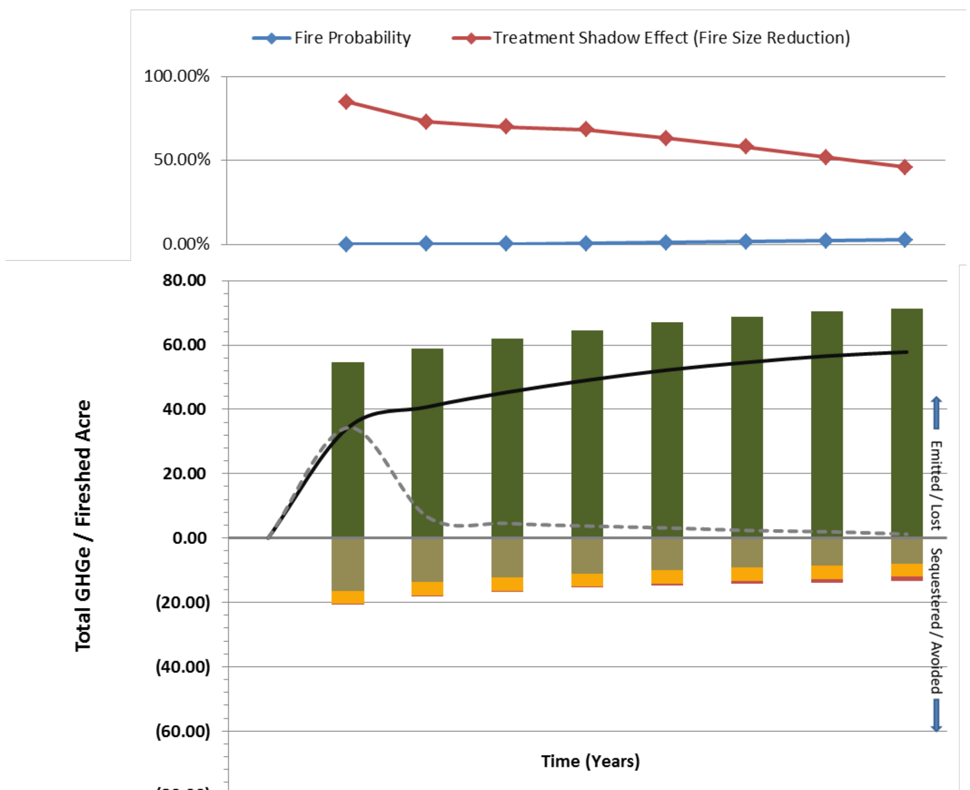


	0	5	10	15	20	25	30	35	40
Wildfire	-	(5.05)	(4.58)	(4.91)	(5.29)	(5.29)	(5.02)	(5.30)	(4.94)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	29.28	36.29	40.64	44.17	47.54	50.41	52.46	54.29
Net	-	29.28	7.01	4.35	3.53	3.37	2.87	2.05	1.84

Figure 35: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "intermediate" fire frequency and constant risk (MFI 50 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 53: Carbon accounting summary for the Private-Harvest management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	0.04%	0.17%	0.39%	0.69%	1.08%	1.55%	2.10%	2.74%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(0.02)	(0.08)	(0.20)	(0.38)	(0.59)	(0.81)	(1.16)	(1.41)
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**34.31**	**40.78**	**45.35**	**49.08**	**52.24**	**54.61**	**56.59**	**57.82**

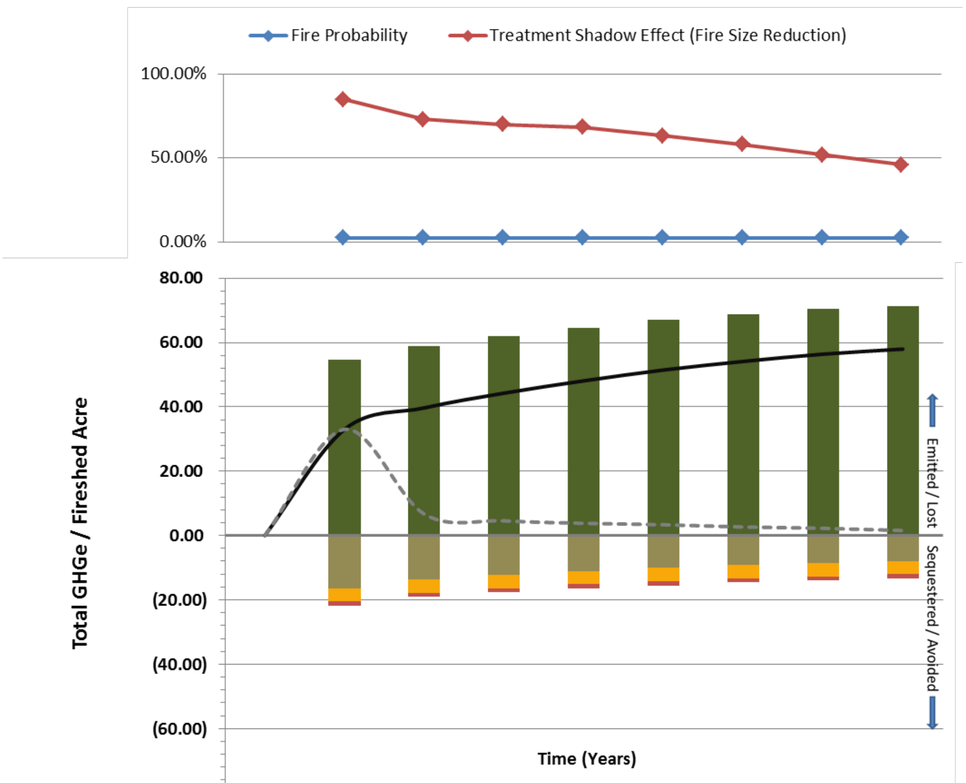


	0	5	10	15	20	25	30	35	40
Wildfire	-	(0.02)	(0.08)	(0.20)	(0.38)	(0.59)	(0.81)	(1.16)	(1.41)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	34.31	40.78	45.35	49.08	52.24	54.61	56.59	57.82
Net	-	34.31	6.47	4.57	3.73	3.16	2.38	1.98	1.23

Figure 36: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "contemporary" fire frequency and variable risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

Table 54: Carbon accounting summary for the Private-Harvest management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided. Full carbon accounting tables for the Alt-SNAMP scenario can be found in the Appendix.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
Net Forest Carbon Liability (Difference - GHG / ac)	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Total Wood Product LCA Benefit (GHG / ac)	-	(20.45)	(17.87)	(16.36)	(15.08)	(14.14)	(13.35)	(12.67)	(12.06)
Probability of Fire	-	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%	2.48%
Total Avoided Wildfire Emissions Benefit (GHG/ac)	-	(1.30)	(1.18)	(1.27)	(1.36)	(1.36)	(1.29)	(1.37)	(1.27)
5) Total Accumulated Benefit or Liability (GHG / ac)	-	33.03	39.68	44.28	48.10	51.47	54.13	56.39	57.96



	0	5	10	15	20	25	30	35	40
Wildfire	-	(1.30)	(1.18)	(1.27)	(1.36)	(1.36)	(1.29)	(1.37)	(1.27)
Biomass Energy	-	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)	(4.08)
Wood Products	-	(16.36)	(13.79)	(12.27)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Forest Carbon	-	54.78	58.74	61.91	64.54	66.98	68.77	70.42	71.29
Accumulated	-	33.03	39.68	44.28	48.10	51.47	54.13	56.39	57.96
Net	-	33.03	6.66	4.60	3.81	3.37	2.66	2.26	1.57

Figure 37: Estimated emissions (GHG equivalent) per acre accounting for avoided wildfire, biomass energy production, wood product life cycles, and forest carbon removal and sequestration under the Private-Harvest management scenario, with "contemporary" fire frequency and constant risk (MFI 200 years). Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon lost, and (negative) values represent net carbon sequestration or emissions avoided.

All Scenarios: Summary

Summary: Forest Carbon

Utilizing a dynamic baseline approach, we examined the net carbon losses (liabilities) created by removing forest biomass for fuel treatment at each five year interval. The volume of GHGs stored in the forest post-treatment was compared to the baseline (Base-BAU scenario), such that all management scenarios began with a net GHG deficit at t>0 due to treatment. These deficits are considered emissions unless offset by wood products, biomass energy production, or avoided wildfire emissions. In the two less intensive management scenarios, deficits of GHGs stored in forest biomass were similar, and increased over the entire 40-year study period. As a proportion of overall stored GHGs (Base-BAU), however, the deficits stay roughly the same. The forest carbon deficit for the Alt-SNAMP scenario, for example, increases from 7.3 GHGe/fireshed acre at year 5 to 11.5 tons GHGe/fireshed acre at year 40, but proportionally the deficit remains at about 3% of the baseline. The deficit for the USFS-Standard scenario increases from 8.5 to 16.9 GHGe/fireshed acre for the same time steps, but only changes proportionally from about 3.4% to 3.9% of the baseline. This suggests that the treatment had little effect on the per-volume rate at which the forest is sequestering carbon under these scenarios. Forest carbon deficits for the Private-Harvest scenario increase from 54.8 to 71.3 tons GHGe/fireshed acre for the 5 and 40 year time steps. As a proportion of the baseline forest carbon, this represents 22% and 17% respectively, suggesting that the treated forest may be sequestering carbon more quickly on a per-volume basis than the untreated forest (baseline).

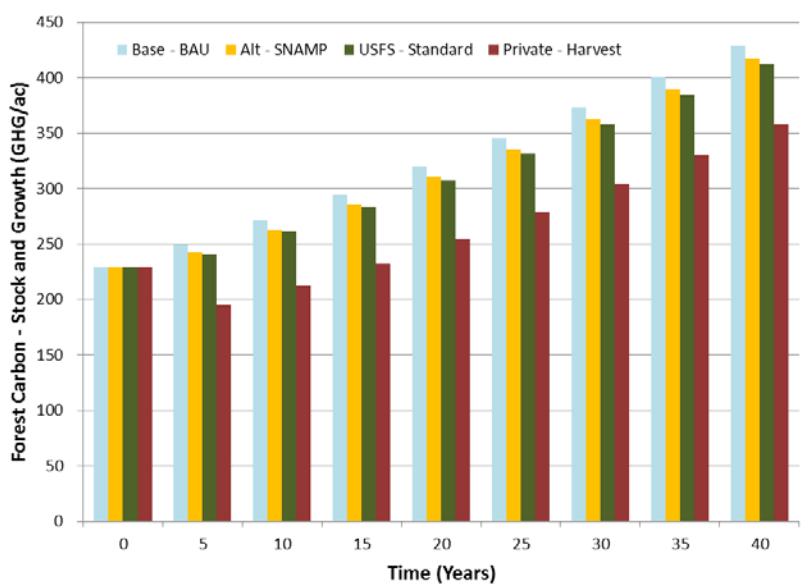


Figure 38: Forest GHG sequestration per acre under Base-BAU and three management scenarios. Net forest carbon in the GHG accounting is the difference between the Base-BAU value and the management scenario.

Summary: Wood Products

The Alt-SNAMP scenario, representing the least intensive treatment approach, removed the least amount of GHGs from the fireshed, and had the least GHGs offset or sequestered each timestep. Removals in the form of merchantable and non-merchantable biomass in the USFS-Standard scenario were almost twice those of the Alt-SNAMP scenario, while the Private-Harvest scenario resulted in nearly nine times the amount of wood fiber removed compared to Alt-SNAMP (Figure 39). Accounting for biomass energy production (offsets) and sequestration wood products (discounted over time), wood product benefits in the Alt-SNAMP scenario decreased from 31% to 24% of removals over the study period. Benefits for the USFS-Standard scenario decreased from 35% to 25% of removals. Benefits in the Private-Harvest scenario decreased from 55% to 33%, with the higher proportions due to greater sequestration in wood products. As a proportion of the GHG deficit created by treatment, wood product GHG benefits for the Alt-SNAMP scenario offset approximately 18% of the deficit at year 5, decreasing to 9% at year 40. Benefits for the USFS-Standard scenario decreased from 33% to 12% of the deficit over the course of the study period, while benefits for the Private-Harvest scenario decreased from 37% to 17%. In this framework, the remaining deficit would need to be offset by avoided wildfire emissions in order for there to be an overall GHG benefit at any time step.

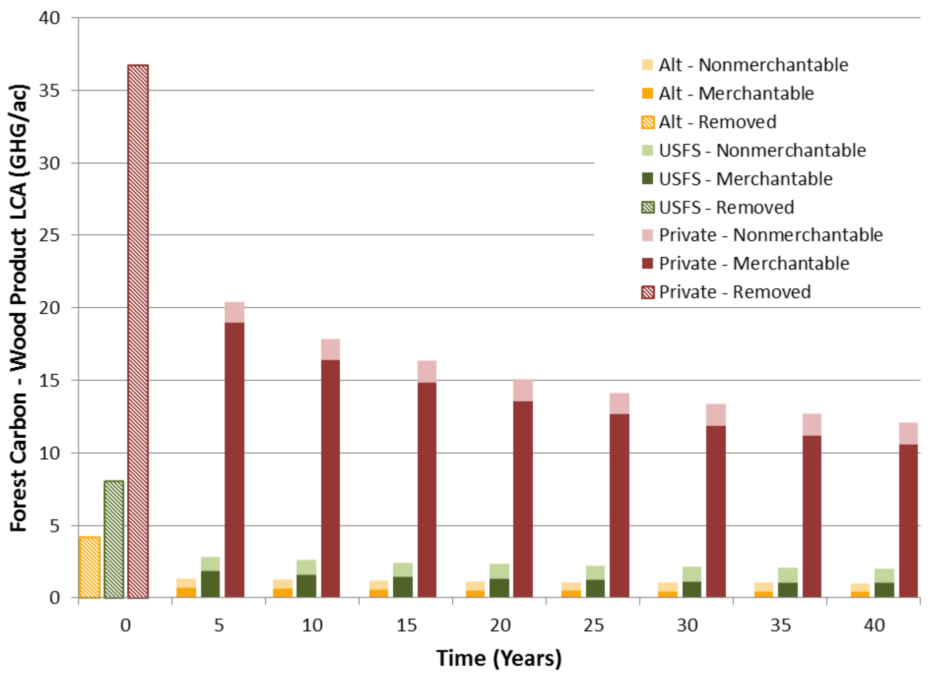


Figure 39: GHGe sequestered or offset (biomass energy) per acre in merchantable and non-merchantable wood products under three management scenarios. Total biomass removed (GHG equivalent) at year 0 shown for reference. Note that in the GHG accounting, these values are tallied as offset emissions (i.e. they are equivalent in magnitude but negative).

Summary: Wildfire

Without accounting for fire risk, over the 40 year time period, expected wildfire emissions under the management scenarios were initially reduced by 56%, 74% and 96% of the baseline for the Alt-SNAMP, USFS Standard, and Private-Harvest scenarios respectively. This effect decreased over time as treatment shadow effects (fire size reduction) declined and forest biomass recovered. Direct emissions reductions and treatment shadow benefits declined the most in the Alt-SNAMP scenario, with a slightly larger but similar trend in the USFS-Standard scenario. Direct emissions reductions and treatment shadow benefits declined the least in the Private-Harvest scenario, indicating that treatments in this scenario produced a longer lasting effect than either of the two less intense scenarios (Figure 40).

Comparatively these patterns remained after discounting expected emissions by fire risk, but variations in expected fire frequency (restored, intermediate or contemporary) and models (variable or constant) had the greatest effect on overall net avoided emissions.

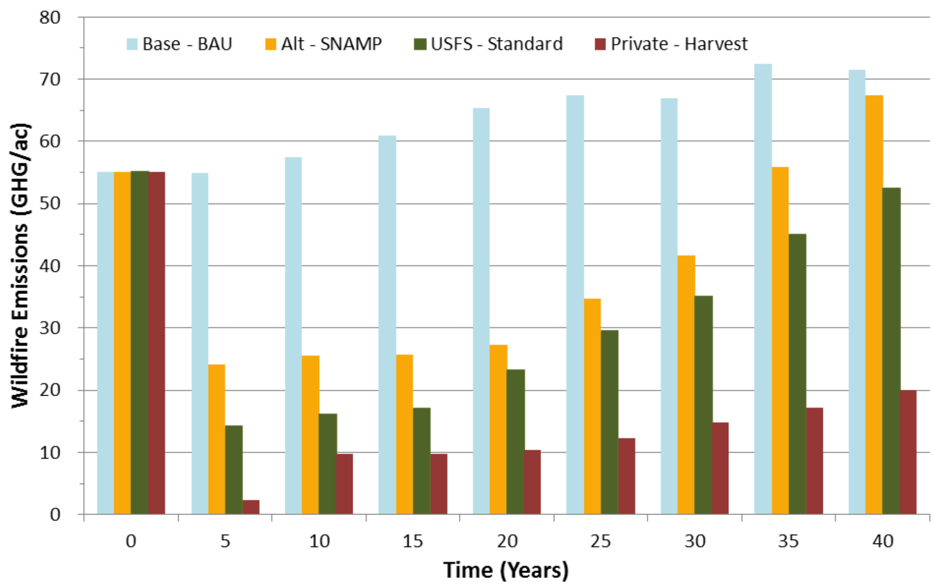


Figure 40: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under Base-BAU and three management scenarios, not accounting for fire risk. Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

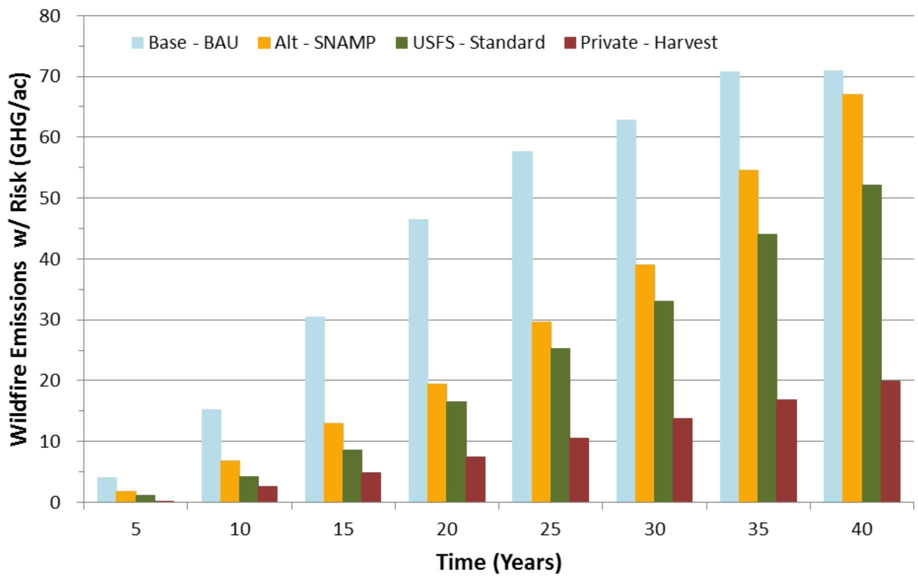


Figure 41: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, with "restored" fire frequency and variable risk model (MFI 15 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

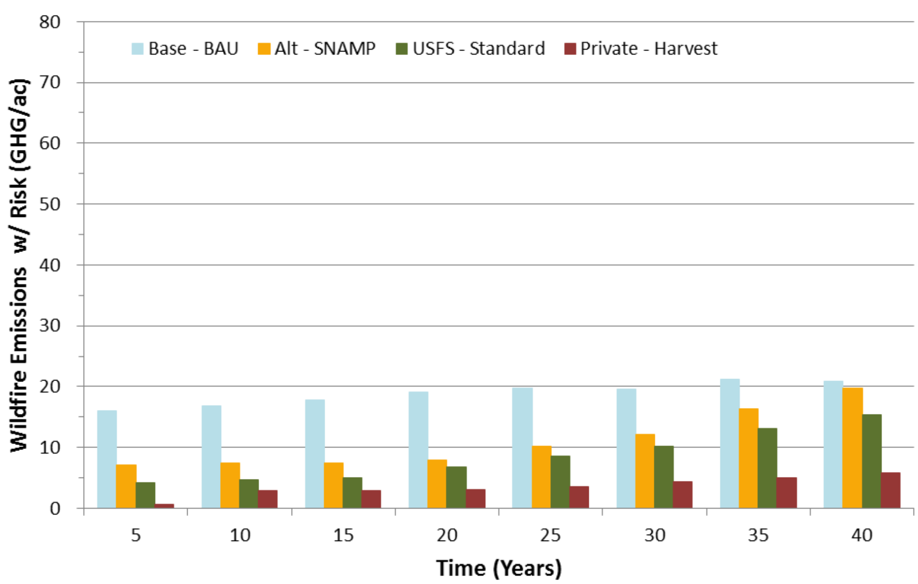


Figure 42: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, with "restored" fire frequency and constant risk model (MFI 15 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

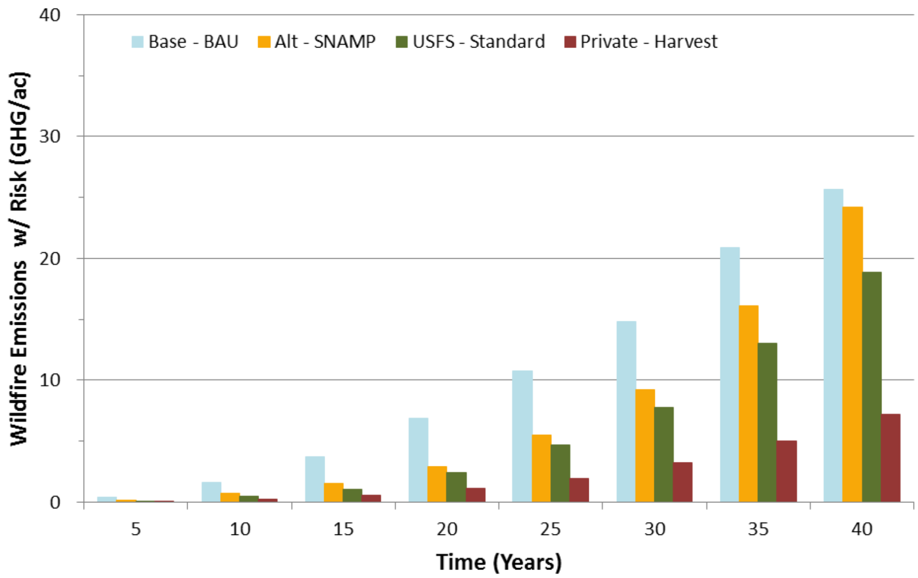


Figure 43: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, with "intermediate" fire frequency and variable risk model (MFI 50 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

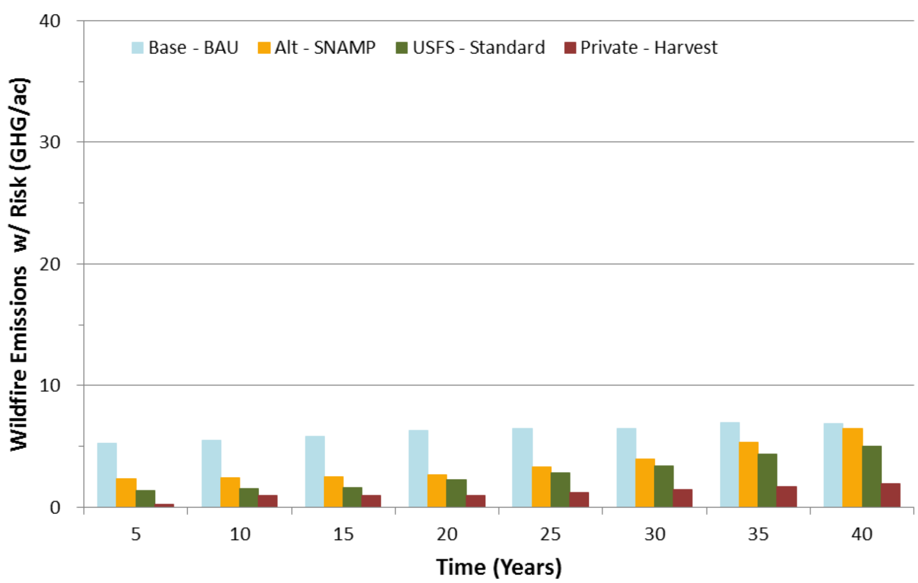


Figure 44: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, with "intermediate" fire frequency and constant risk model (MFI 50 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

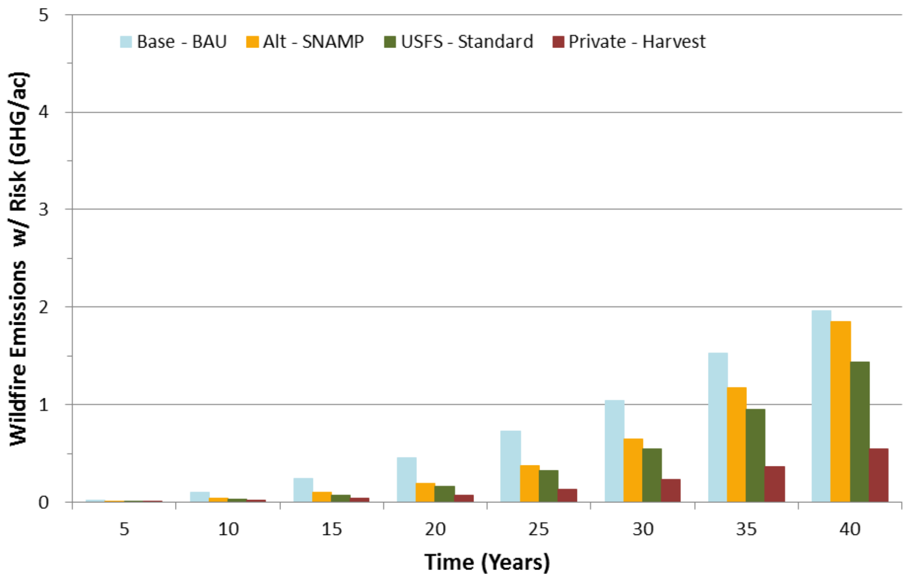


Figure 45: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

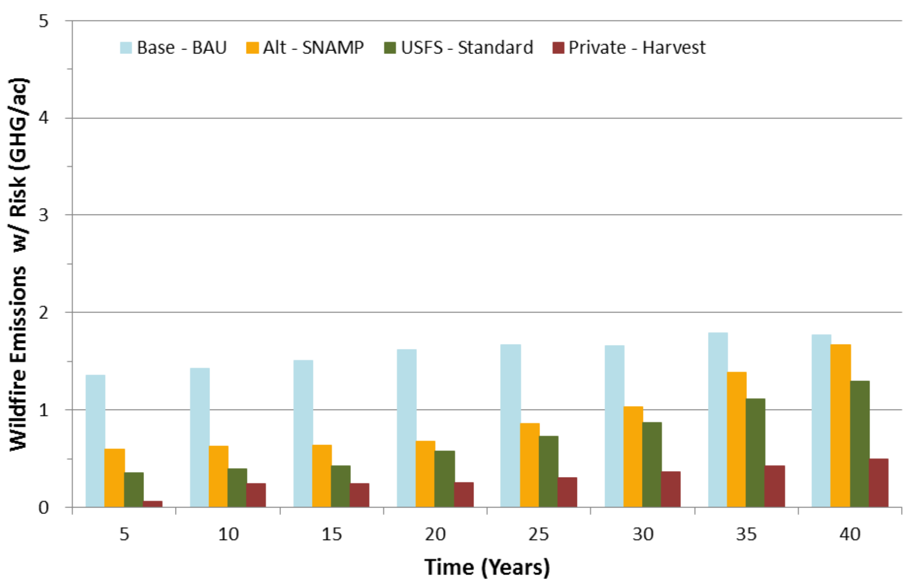


Figure 46: Total emissions (direct emissions modified by treatment shadow effect) expected per acre under baseline (Base-BAU) scenario and three management scenarios, with "contemporary" fire frequency and constant risk model (MFI 200 years). Avoided emissions are the difference between the baseline (Base-BAU) scenario and the management scenarios.

Table 55: Summary of total accumulated GHG benefits or liabilities per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "restored" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

	Time (yrs)							
Frequency - Risk	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Restored Frequency (MFI 15 Years)								
Alt-SNAMP								
Variable	3.73	(1.79)	(10.30)	(19.05)	(19.29)	(14.49)	(6.14)	6.54
Constant	(2.98)	(2.63)	(2.95)	(3.14)	(0.87)	1.89	5.20	9.37
USFS-Standard								
Variable	2.70	(3.73)	(13.35)	(19.93)	(21.02)	(17.23)	(12.75)	(3.95)
Constant	(6.16)	(4.82)	(4.20)	(2.34)	0.31	3.34	5.95	9.37
Private-Harvest								
Variable	30.43	28.21	19.96	10.43	5.73	6.45	3.85	8.22
Constant	18.99	26.97	30.64	33.40	36.75	40.19	41.66	44.24

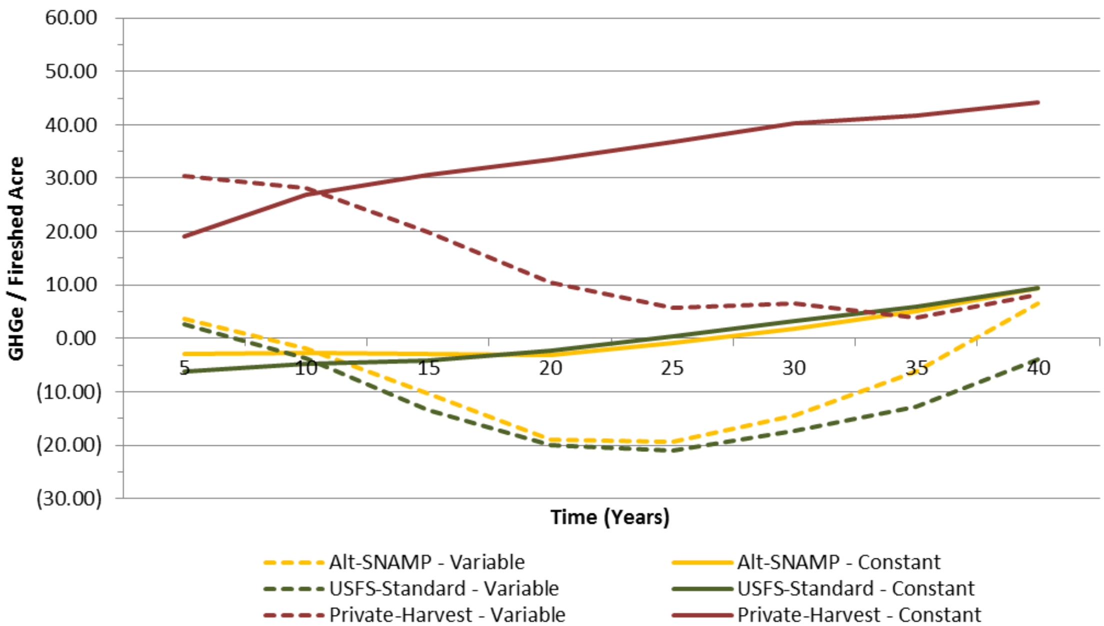


Figure 47: Total accumulated GHG benefits per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "restored" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

Table 56: Summary of total accumulated GHG benefits or liabilities per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "intermediate" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

	Time (yrs)							
Frequency - Risk	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Intermediate Frequency (MFI 50 Years)								
Alt-SNAMP								
Variable	5.81	5.81	5.19	3.97	3.46	3.68	5.26	9.10
Constant	3.06	3.62	3.94	4.31	5.54	6.85	8.44	10.17
USFS-Standard								
Variable	5.44	6.11	5.92	5.52	5.33	5.58	6.04	8.09
Constant	1.81	3.27	4.37	5.90	7.73	9.57	11.29	13.09
Private-Harvest								
Variable	33.97	39.56	42.45	43.67	44.05	43.87	41.84	40.79
Constant	29.28	36.29	40.64	44.17	47.54	50.41	52.46	54.29

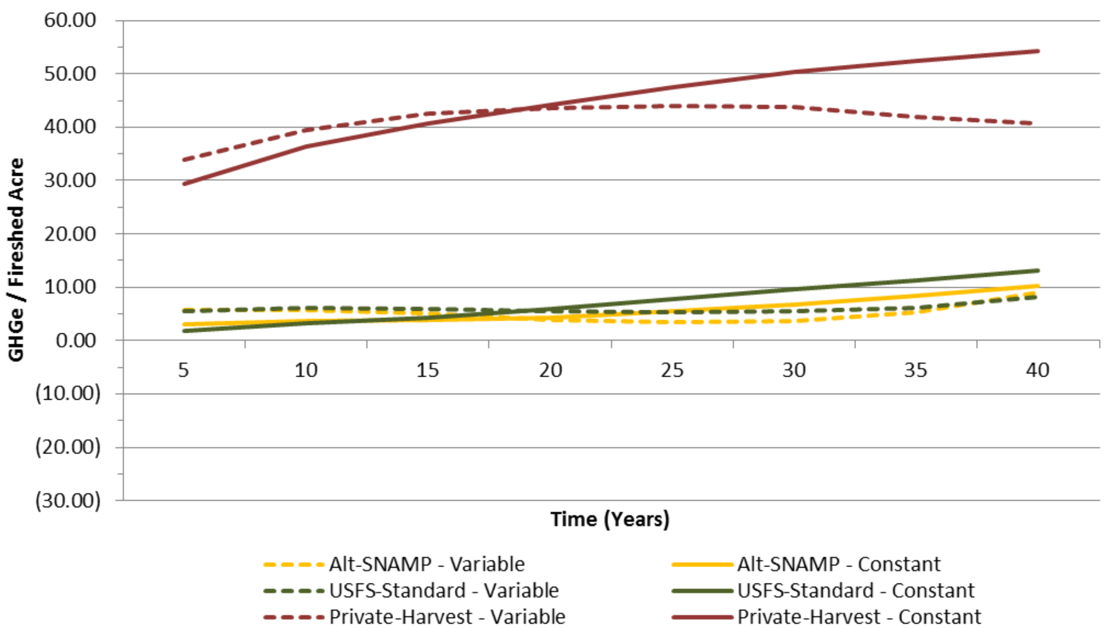


Figure 48: Total accumulated GHG benefits per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "intermediate" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

Table 57: Summary of total accumulated GHG benefits or liabilities per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "contemporary" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

				Time (yrs)				
Frequency - Risk	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Contemporary Frequency (MFI 200 Years)								
Alt-SNAMP								
Variable	6.01	6.63	7.19	7.71	8.33	8.89	9.68	10.44
Constant	5.26	5.90	6.45	7.03	7.87	8.66	9.62	10.46
USFS-Standard								
Variable	5.70	7.17	8.40	9.66	10.96	12.13	13.34	14.39
Constant	4.71	6.22	7.49	8.91	10.43	11.84	13.24	14.44
Private-Harvest								
Variable	34.31	40.78	45.35	49.08	52.24	54.61	56.59	57.82
Constant	33.03	39.68	44.28	48.10	51.47	54.13	56.39	57.96

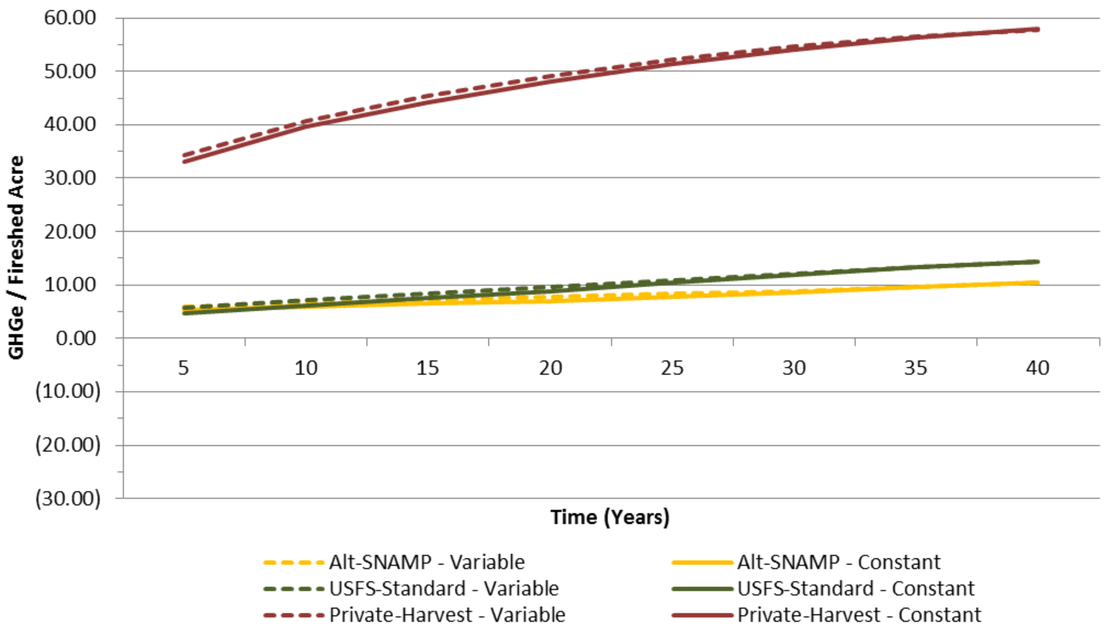


Figure 49: Total accumulated GHG benefits per acre, accounting for forest carbon removal and sequestration, wood product life cycles, biomass energy production, and avoided wildfire emissions, under "contemporary" fire frequency. Values (metric tons GHGe) are in terms of emissions, where positive values represent net emissions or equivalent carbon loss, and (negative) values represent net carbon sequestration or equivalent avoided emissions.

Discussion

In western forests altered by a century of fire suppression, logging, and other management activity, the need for fuel treatment as a means to reduce the risk of severe wildfire events is now broadly accepted by forest owners and managers, and implementation of treatments has been increasing over the last several decades, concurrent with increasing study of and concern over greenhouse gas emissions and climate change. There have been numerous published studies documenting the positive effects of fuel treatments on moderating potential fire behavior and severity (Collins and Stephens 2012, Safford et al. 2012) and potential effects on other biological resources (Stephens et al. 2012). Much of the forested land in question (e.g. lower- and middle-elevation pine and mixed-conifer forests in the Sierra Nevada) and associated ecological processes developed with wildfire as a relatively frequent and widespread disturbance event, typically of low to moderate or mixed severity (Sugihara et al. 2006). However, since adoption of comprehensive fire exclusion policies in the early 20th century, the US has been particularly effective at suppressing the vast majority of wildfire ignitions (Dombeck et al. 2004) leading to changes in fuel hazards, forest structure, and ecosystem health (Parsons and DeBendetti 1979, McKelvey et al 1996) that can promote uncharacteristically severe wildfire. Despite increases over recent decades in average annual area burned (Stephens 2005, Stephens and Ruth 2005), estimates of contemporary fire frequency and extent suggest relatively low annual probabilities of fire (e.g. < 1%) in the very areas that are being treated or considered for treatment today (Moritz et al. 2009, Rhodes and Baker 2008).

A primary goal of many management plans for altered forests on public land is to restore some level of "resiliency", allowing them to withstand wildfire without severe impacts that may alter systems for centuries. These plans often draw from our understanding of pre-historic fire regimes and forest structures, but restoration of relatively frequent fire to these forest types which have long been without it, in some cases for over a century, faces serious hurdles and may not even be desirable in systems faced with issues such as a growing wildland-urban interface. Now well into the 21st century, fuel management looks to remain a primary tool for land managers tasked with creating healthy and resilient forests as well as protecting resources, property, and human lives, and doing so in an economically sustainable way.

Forested lands can be large sinks for terrestrial carbon, but may also pose a risk of large emissions events releases associated with severe wildfire. Much recent work, including this project, has examined the seemingly competing goals of sequestering carbon in forest biomass, and removing carbon for fire protection, potentially avoiding large emission events (Mitchell et al. 2008, North et al. 2009, Stephens et al 2009b, Ager et al. 2010, Cathcart et al. 2010, Hurteau and North 2010, Campbell et al. 2011, Reinhardt and Holsinger 2010, and others). In the face of a changing climate, the question of whether fuel treatments in at-risk forests can promote long-term carbon sequestration by providing net GHG emissions reductions through avoided wildfire and other offsets has come to the forefront. As carbon markets in the US come online, such as that initiated by California's A.B. 32, the methodology developed in this project is intended to provide a framework, based on current science, for quantifying the GHG benefits or liabilities resulting from fuels treatment, in order to facilitate evaluation of projects for potential emission reduction credits in places such as Placer County.

The management scenarios applied in this study represent three different approaches to fuel treatment that might be undertaken in a location such as Last Chance or elsewhere in Placer County. The Alt-SNAMP and USFS-Standard scenarios were designed to be typical of what might take place on federal lands or the like, where large scale commercial harvesting or other intensive activities may be restricted or constrained by management goals. These types of approaches, where the focus is primarily upon removing ladder fuels and smaller diameter trees and treating surface fuels, are generally accepted as being effective at modifying fire behavior and reducing the risk of large scale catastrophic events (e.g. Stephens et al 2009a), though the placement, pattern, intensity and size of treatments over large landscapes is still under scrutiny (Collins et al. 2011). In the entire scale of treatment intensity, these two scenarios are not vastly different, but they allowed us to examine what might be considered a relatively lower intensity treatment approach (Alt-SNAMP), as well as an approach more typical of current practices. The Private-Harvest management scenario allowed us to evaluate a more intensive fuel treatment strategy, based on commercial harvesting of larger diameter trees.

While sequestration in durable wood products, wood product waste, and offsets from biomass energy production were important and significant in all three scenarios, they were never enough to create a net GHG benefit overall. The highest proportional offset from all wood products was 55% of the total GHG deficit created by treatment at year 5 in the Private-Harvest scenario, declining from there on. Creating a net GHG benefit at any time step was therefore dependent upon the remaining deficit being offset by avoided wildfire. The amount of avoided wildfire was highly dependent upon our estimates and models for the risk of fire.

The only level of fire probability (frequency) that resulted in enough avoided emissions to offset carbon removals was the "restored" frequency, with an expected fire return interval of 15 years, when applied to the Alt-SNAMP and USFS-Standard scenarios. Both the variable and constant risk models resulted in overall net benefits for these treatment scenarios. In both scenarios, the variable risk model resulted in increasing benefits to year 25, followed by decreasing benefits to the end of the study period. Increasing avoided emissions were largely the result of increasing probability of wildfire (~50% by year 15) but this effect was countered by decreasing treatment shadow effect (fire size reduction). These two values (probability of wildfire and treatment shadow effect) had a similarly important effect on avoided emissions when using the constant risk model. Under a restored fire frequency and constant risk model, the five year probability of wildfire (~29%) resulted in enough avoided emissions at each time step to create benefits immediately (year 5) and lasting to approximately year 25. Avoided emissions decreased due to changes in direct emissions expected, but were primarily due to reduced treatment effectiveness (decreasing treatment shadow effect). Fire size reduction was initially 56% and 68% for the Alt-SNAMP and USFS-Standard scenarios, but by year 40 had decreased to 3% and 14% respectively. Variations in avoided emissions, therefore, were affected by changes in direct emissions, reductions in fire size, and level of fire risk, with the latter two having the greatest effect. Fuel treatment maintenance could theoretically extend GHG benefits by keep fire size reductions high, as well as creating additionality from wood products and biomass energy production. In the Private-Harvest scenario, avoided emissions (with wood product offsets) were never enough to create an overall GHG benefit, even at the highest probability of wildfire.

Given contemporary land management constraints and goals, as well as structural changes incurred over the last century, the likelihood of restoring a fire regime on a significant portion of the landscape with an expected fire return interval of 15 years in the foreseeable future is low, and would require substantial changes regarding suppression of fire, including the expansion of "Wildland Fire Use" (WFU), "managed wildfire", "ecologically beneficial fire", or "prescribed natural fire" outside of wilderness areas. It should be noted that there have been efforts to expand the use of managed wildfires outside of wilderness areas on national forest lands in the Sierras (Striplan and Papa 2012) (Personal communications with Brandon Collins, PSW). Even with an expected interval of 50 years ("intermediate" frequency), avoided wildfire supplemented by wood product offsets was not enough to create net carbon benefits. Contemporary fire probability (MFI 200 years or greater) was even less effective, with the probability of wildfire never rising above 3% using either variable or constant risk models.

Though many recent studies have focused on the relationship between carbon sequestration and fuel treatment, few have examined it over a long time period with explicit quantification of treatment effectiveness and fire risk, as was done here. Ager et al. (2010) used many of the same tools (FVS, RANDIG) to estimate carbon emissions before and after treatment in a novel way (by flame length), but found a similar carbon liability when subjecting the landscape in southern Oregon to fire immediately after treatment. North and Hurteau (2011), examining actual wildfire in 12 sites across California, found that areas treated for fuel reduction and subsequently burned by wildfires retained a higher level of live tree carbon, compared with untreated areas, which had larger pools of dead and decaying carbon. Studies in the Teakettle Experimental Forest (North et al. 2009) demonstrate that despite fuel treatment effectiveness at changing fire behavior, carbon liabilities exist immediately post treatment. They suggest, however that thinning from below and retention of large, fire resistant trees can potentially stabilize carbon stocks. Examining fuel treatments in several Rocky Mountain forest types, Reinhardt and Holsinger (2010) found significant effects in terms of fire behavior reduction, but no long term increases in forest carbon stocks. In the study closest to Last Chance, Stephens et al. (2009b) demonstrate decreased vulnerability of treated forests to wildfire related Carbon loss at Blodgett Research Forest immediately after treatment, though this study did not analyze GHG benefits over long time periods.

The carbon emission offset framework provides a novel yet robust way of evaluating projects for GHG benefits. While several studies have examined fuel treatment effects on carbon immediately post fire, or in terms of relative (conditional) probabilities, most do not take into account the actual expected risk of fire. In all evaluations, it is assumed that fire will impact the study site at some point, but this case study shows that the actual likelihood of fire impacting the landscape is an important consideration, especially given that fuel treatments have an effective life span (Chiono et al. 2012). The framework provides a means for quantifying the benefits over long periods of time, as well as broad spatial scales. In this case study, net GHG benefits were only obtained from fuel treatments when the probability of wildfire was relatively high (15 year return interval), a condition that would likely be difficult to replicate in reality, particularly at a landscape scale. Optimizing treatments to maximize fire behavior reduction, retention of large fire resistant trees, treatment longevity, and wood product and biomass offsets may be important to balancing the goals of carbon sequestration and forest resiliency to fire. Intermediate maintenance treatments may be still needed after 15-20 years to maintain long-term effectiveness of fuel treatments in reducing potential fire severity (Chiono et al. 2012), though the need for treatment should be based on site specific vegetation development for previously treated areas.

Though we make a thorough attempt in this framework to consider time, space, the fate of carbon, and fire probabilities, there are important assumptions and liabilities associated with its application. Benefits or liabilities (quantities of GHGs removed, lost, sequestered or avoided) are all calculated in relation to a dynamic baseline, i.e. what we expect to happen if the landscape is left untreated. Infrastructure and facilities for biomass utilization are assumed to be available and viable. Merchantable wood is assumed to be going to its highest and best use. Treatment effects on wildfire may go beyond the treatment boundaries themselves, and we assume that they can be reasonably approximated by measuring reduction in fire size. Fire hazard evaluation is limited by uncertainty in fire weather information. While increasing fire hazard is accounted for in forest growth modeling, fire risk changes through time and if taken into consideration, we assume it can be reasonably modeled with a statistical probability distribution (i.e. Weibull). If using a variable/stochastic model of risk, we assume that treatment occurs near that beginning of an expected fire interval, i.e. fire risk increases from zero at the time of treatment. These and other limitations and assumptions may be addressed in future studies.

Conclusions

The carbon emission offset framework developed for this project provides a novel yet robust methodology for quantifying at-risk landscapes and evaluating fuel treatment projects and their impact on the fireshed over long periods of time. It takes into consideration fuel treatment effects and life spans, wood product utilization, and the probability of wildfire impacting the landscape. In our case study of the Last Chance area, we demonstrated that:

- Fuel treatments had significant impacts on potential wildfire emissions, both direct (emissions from within the treatments themselves) and indirect (in the form of reduced expected fire size).
- The effects of treatment on fire size deteriorated over time. To a certain point (i.e. the effective life span of the treatments), these effects had an important impact on avoided emissions, at least for the "thin from below" treatments (Alt-SNAMP and USFS-Standard).
- GHG storage and offsets from wood products and biomass energy production created significant GHG benefits, but even in the most intensive management scenario (Private-Harvest) were never more than 50% of the net GHG deficit created by biomass removal in fuel treatments. The remaining deficit had to be offset by avoided wildfire emissions in order to create a net GHG benefit at any time step.
- Avoided wildfire emissions (and thus net GHG benefits or liabilities) were highly sensitive to the probability of wildfire and the form of its application (e.g. constant or variable).
- Net GHG benefits were only realized when the probability of wildfire was high (15 year expected return interval), and only for the thin-from-below treatments (Alt-SNAMP and USFS-Standard).
- The scenario based on commercial harvest of large diameter trees (Private-Harvest) realized no net GHG benefit at any point in the study period, using any expected fire frequency or risk model. Though there was a significant and long lasting effect on fire behavior, avoided emissions were never enough to compensate for removal of large amounts of stored carbon during treatment.
- Balancing the goals of carbon sequestration and forest resiliency to fire may require optimizing treatments to maximize fire behavior reduction, retention of large fire resistant trees, treatment longevity, and wood product and biomass offsets.
- While GHG emissions are a current area of focus within forest management, interpretation of findings from this study should be considered within the framework of findings from previously published studies that have quantified additional ecosystem co-benefits of reducing stand density, actively restoring forest structure, and reintroducing fire as an ecosystem process at a landscape scale. Potential issues to consider for future studies include to:
    - Complete a "full-cycle" analysis that also considers the carbon benefits of wood products derived from thinning in terms of avoiding more carbon-intensive building products like steel and concrete. When such benefits are included, the overall accounting related to thinning to reduce fire effects/protect forest carbon stores, provide products, and provide biomass energy may be even more positive.
    - Analyze an increase in the number of acres treated with the "thin from below" approach to see if there are greater carbon benefits to be derived from decreasing wildfire effects on a larger number of acres.
    - Analyze the effects of implementing maintenance of treatments at various time intervals to determine whether longer term or larger carbon benefits are possible.

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Models and Linkages

The carbon emission offset framework developed for this study is comprised of several process-based models linked to provide localized estimates of potential relative emissions reductions.

1) Fireshed Delineation: To delineate the basic unit of land management, within which fuel treatments are intended to have an effect. This step is accomplished largely by custom geographic and statistical analysis, as well as expert opinion. Fireshed delineations are the units within which "per acre" basis emissions are calculated.
2) Land cover classification and vegetation quantification: To characterize vegetation composition at a fine scale, creating landscapes for fire behavior and tree growth analysis. This step is accomplished through a framework developed by SIG, which includes object-based image analysis (OBIA) and other spatial analysis techniques, and is collectively termed GreenIntel™. Land cover classifications stand delineations are used in conjunction with field data to assign vegetation and fuel characteristics to the landscape in a manner appropriate for fire behavior and tree growth modeling.
3) Forest Tree Growth and Carbon Storage: To assess the forest fuel treatment impact on forest growth rate and carbon sequestration (change in "carbon-on-the-stump"). Forest tree growth and changes in fire fuels are estimated in the US Forest Service Forest Vegetation Simulator (FVS) model, with the Fire and Fuels Extension (FFE) using local variants.
4) Wildfire Reduction: To assess the forest fuel treatment impact on reducing the severity of wildfires. This involves modeling wildfire behavior under various weather scenarios, quantifying long-term conditional fire probability, and resulting fuel consumption (burn rates) and fire sizes. Wildfire behavior is modeled using the FlamMap and RANDIG systems, which are spatial implementations of the Rothermel (1972) fire spread model. Changes in wildfire characteristics due to fuel treatments are used to examine changes in carbon storage and GHG emissions.
5) Wildfire Risk: To estimate the long-term fire occurrence probability for each portion of the landscape. This step is accomplished using the Maxent statistical framework, a recently developed probabilistic distribution modeling tool, to generate spatially explicit fire probability maps. Training data for Maxent is derived from mapped fire histories for Plumas County. Probability of fire occurrence is used to modify per-acre estimates of GHG emissions for each watershed.
6) Green House Gas Emissions: To assess the forest fuel treatment impact on reducing the emissions from wildfires for cases with and without forest fuel treatment. This step is accomplished using the CONSUME fire emissions model. GHG emissions are analyzed with carbon sequestration estimates to derive net carbon storage.

The simulation models used in this study were refined and calibrated using empirical field study data from other research projects being conducted by Spatial Informatics Group, the University of California, the US Forest Service and other partners.

Full GHG Accounting Tables

Table 58: Carbon accounting results for the Alt-SNAMP management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	0.01	(0.65)	(1.21)	(1.72)	(1.48)	(2.56)	(1.92)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(2.27)	(8.49)	(16.97)	(25.82)	(26.26)	(22.29)	(13.61)	(2.10)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(2.29)**	**(8.48)**	**(17.63)**	**(27.02)**	**(27.98)**	**(23.77)**	**(16.17)**	**(4.02)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**3.73**	**(1.79)**	**(10.30)**	**(19.05)**	**(19.29)**	**(14.49)**	**(6.14)**	**6.54**

Table 59: Carbon accounting results for the Alt-SNAMP management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.08)	0.01	(0.38)	(0.50)	(0.59)	(0.46)	(0.77)	(0.56)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(8.92)	(9.32)	(9.89)	(10.62)	(8.96)	(6.94)	(4.06)	(0.62)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(9.00)**	**(9.31)**	**(10.27)**	**(11.12)**	**(9.55)**	**(7.40)**	**(4.83)**	**(1.18)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**(2.98)**	**(2.63)**	**(2.95)**	**(3.14)**	**(0.87)**	**1.89**	**5.20**	**9.37**

Table 60: Carbon accounting results for the Alt-SNAMP management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	0.00	(0.08)	(0.18)	(0.32)	(0.35)	(0.76)	(0.69)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.21)	(0.88)	(2.05)	(3.83)	(4.90)	(5.26)	(4.02)	(0.76)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.21)**	**(0.87)**	**(2.13)**	**(4.01)**	**(5.22)**	**(5.61)**	**(4.77)**	**(1.45)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.81**	**5.81**	**5.19**	**3.97**	**3.46**	**3.68**	**5.26**	**9.10**

Table 61: Carbon accounting results for the Alt-SNAMP management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.03)	0.00	(0.13)	(0.16)	(0.19)	(0.15)	(0.25)	(0.19)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(2.94)	(3.07)	(3.26)	(3.50)	(2.95)	(2.28)	(1.34)	(0.20)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(2.96)**	**(3.07)**	**(3.38)**	**(3.66)**	**(3.14)**	**(2.44)**	**(1.59)**	**(0.39)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**3.06**	**3.62**	**3.94**	**4.31**	**5.54**	**6.85**	**8.44**	**10.17**

Table 62: Carbon accounting results for the Alt-SNAMP management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	0.00	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.05)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.01)	(0.06)	(0.13)	(0.25)	(0.33)	(0.37)	(0.29)	(0.06)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.01)**	**(0.06)**	**(0.14)**	**(0.26)**	**(0.35)**	**(0.39)**	**(0.35)**	**(0.11)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**6.01**	**6.63**	**7.19**	**7.71**	**8.33**	**8.89**	**9.68**	**10.44**

Table 63: Carbon accounting results for the Alt-SNAMP management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

ALT - SNAMP									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
ALT SNAMP - Forest Sequestration (GHG / ac)	(229)	(242)	(263)	(286)	(310)	(336)	(363)	(390)	(418)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**7.34**	**7.90**	**8.48**	**9.09**	**9.75**	**10.33**	**11.05**	**11.55**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)	(0.58)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Merch Going to Wood Products (GHG / ac)	-	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Wood Products Still in End Use (GHG / ac)	-	(0.59)	(0.52)	(0.47)	(0.42)	(0.39)	(0.36)	(0.33)	(0.31)
Merch Residuals Diverted to Waste (GHG / ac)	-	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.04)	(0.01)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(0.73)	(0.63)	(0.57)	(0.53)	(0.49)	(0.46)	(0.43)	(0.41)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(1.32)**	**(1.22)**	**(1.16)**	**(1.11)**	**(1.07)**	**(1.04)**	**(1.02)**	**(0.99)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
ALT SNAMP - Direct Emissions (GHG / ac)	55	55	57	60	64	65	65	70	70
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Avoided Wildfire Emissions (GHG / ac)	-	(0.26)	0.04	(1.31)	(1.70)	(2.01)	(1.58)	(2.62)	(1.93)
Net Direct Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.01)	0.00	(0.03)	(0.04)	(0.05)	(0.04)	(0.06)	(0.05)
Treatment Shadow									
% Change in Fire Size	0%	-56%	-56%	-56%	-56%	-46%	-36%	-19%	-3%
Indirect Emissions									
Treatment Shadow Effect Avoided Emissions (GHG / ac)	-	(30.58)	(31.96)	(33.90)	(36.41)	(30.72)	(23.77)	(13.93)	(2.12)
Net Indirect Avoided Wildfire Emissions w/Risk (GHG /ac)	-	(0.76)	(0.79)	(0.84)	(0.90)	(0.76)	(0.59)	(0.34)	(0.05)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.76)**	**(0.79)**	**(0.87)**	**(0.94)**	**(0.81)**	**(0.63)**	**(0.41)**	**(0.10)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.26**	**5.90**	**6.45**	**7.03**	**7.87**	**8.66**	**9.62**	**10.46**

Table 64: Carbon accounting results for the USFS-Standard management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.25)	(1.06)	(2.71)	(4.37)	(5.65)	(6.09)	(8.34)	(8.97)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(2.77)	(9.91)	(19.21)	(25.52)	(26.74)	(23.76)	(18.32)	(9.89)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.02)**	**(10.98)**	**(21.93)**	**(29.89)**	**(32.39)**	**(29.85)**	**(26.67)**	**(18.87)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**2.70**	**(3.73)**	**(13.35)**	**(19.93)**	**(21.02)**	**(17.23)**	**(12.75)**	**(3.95)**

Table 65: Carbon accounting results for the USFS-Standard management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.98)	(1.17)	(1.58)	(1.80)	(1.93)	(1.90)	(2.49)	(2.64)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(10.90)	(10.89)	(11.20)	(10.50)	(9.13)	(7.39)	(5.47)	(2.91)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(11.88)**	**(12.06)**	**(12.78)**	**(12.30)**	**(11.06)**	**(9.29)**	**(7.96)**	**(5.54)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**(6.16)**	**(4.82)**	**(4.20)**	**(2.34)**	**0.31**	**3.34**	**5.95**	**9.37**

Table 66: Carbon accounting results for the USFS-Standard management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.11)	(0.33)	(0.65)	(1.05)	(1.44)	(2.46)	(3.24)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.26)	(1.02)	(2.33)	(3.78)	(4.99)	(5.60)	(5.41)	(3.58)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.28)**	**(1.13)**	**(2.65)**	**(4.43)**	**(6.04)**	**(7.04)**	**(7.87)**	**(6.82)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.44**	**6.11**	**5.92**	**5.52**	**5.33**	**5.58**	**6.04**	**8.09**

Table 67: Carbon accounting results for the USFS-Standard management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.32)	(0.38)	(0.52)	(0.59)	(0.63)	(0.62)	(0.82)	(0.87)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(3.59)	(3.59)	(3.69)	(3.46)	(3.01)	(2.43)	(1.80)	(0.96)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.91)**	**(3.97)**	**(4.21)**	**(4.05)**	**(3.64)**	**(3.06)**	**(2.62)**	**(1.83)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**1.81**	**3.27**	**4.37**	**5.90**	**7.73**	**9.57**	**11.29**	**13.09**

Table 68: Carbon accounting results for the USFS-Standard management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	0	5	10	15	20	25	30	35	40
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	(0.01)	(0.02)	(0.04)	(0.07)	(0.10)	(0.18)	(0.25)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.06)	(0.15)	(0.25)	(0.34)	(0.39)	(0.39)	(0.27)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.02)**	**(0.07)**	**(0.17)**	**(0.29)**	**(0.41)**	**(0.49)**	**(0.57)**	**(0.52)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**5.70**	**7.17**	**8.40**	**9.66**	**10.96**	**12.13**	**13.34**	**14.39**

Table 69: Carbon accounting results for the USFS-Standard management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

USFS - STANDARD									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
USFS STANDARD - Forest Sequestration (GHG / ac)	(229)	(241)	(261)	(284)	(307)	(332)	(358)	(385)	(412)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**8.54**	**9.81**	**11.00**	**12.25**	**13.58**	**14.76**	**15.98**	**16.92**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
% Slash Diverted to Biomass Utilization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass LCA (GHG / ac)	-	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)	(0.99)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79
Merch Going to Wood Products(GHG / ac)	-	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)	(1.67)
Wood Products Still in End Use (GHG / ac)	-	(1.46)	(1.30)	(1.17)	(1.06)	(0.97)	(0.89)	(0.83)	(0.77)
Merch Residuals Diverted to Waste (GHG / ac)	-	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)	(1.12)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)	(0.28)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(0.11)	(0.03)	(0.01)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(1.83)	(1.58)	(1.43)	(1.31)	(1.22)	(1.14)	(1.08)	(1.02)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(2.82)**	**(2.57)**	**(2.42)**	**(2.30)**	**(2.21)**	**(2.13)**	**(2.07)**	**(2.01)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
USFS STANDARD - Direct Emissions (GHG / ac)	55.15	51.61	53.42	55.50	59.26	60.80	60.46	63.88	62.44
BASE - Direct Emissions (GHG / ac)	55.15	54.95	57.43	60.92	65.43	67.41	66.96	72.42	71.48
Net Direct Wildfire Emissions (GHG / ac)	-	(3.34)	(4.01)	(5.42)	(6.17)	(6.61)	(6.50)	(8.54)	(9.04)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.08)	(0.10)	(0.13)	(0.15)	(0.16)	(0.16)	(0.21)	(0.22)
Treatment Shadow									
% Change in Fire Size	0%	-68%	-65%	-63%	-55%	-46%	-38%	-26%	-14%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(37.37)	(37.33)	(38.38)	(35.99)	(31.29)	(25.33)	(18.75)	(9.97)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.92)	(0.92)	(0.95)	(0.89)	(0.77)	(0.63)	(0.46)	(0.25)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(1.01)**	**(1.02)**	**(1.08)**	**(1.04)**	**(0.94)**	**(0.79)**	**(0.68)**	**(0.47)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**4.71**	**6.22**	**7.49**	**8.91**	**10.43**	**11.84**	**13.24**	**14.44**

Table 70: Carbon accounting results for the Private-Harvest management scenario, under a "restored" fire frequency and variable risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
					Time (yrs)				
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**7.43%**	**26.56%**	**50.06%**	**70.90%**	**85.47%**	**93.78%**	**97.72%**	**99.28%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.44)	(1.52)	(4.24)	(7.34)	(10.66)	(12.43)	(17.09)	(18.47)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(3.47)	(11.13)	(21.35)	(31.69)	(36.44)	(36.54)	(36.82)	(32.55)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(3.90)**	**(12.65)**	**(25.59)**	**(39.03)**	**(47.10)**	**(48.98)**	**(53.91)**	**(51.02)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**30.43**	**28.21**	**19.96**	**10.43**	**5.73**	**6.45**	**3.85**	**8.22**

Table 71: Carbon accounting results for the Private-Harvest management scenario, under a "restored" fire frequency and constant risk model (MFI 15 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	15	15	15	15	15	15	15	15	15
Probability of Fire	**-**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**	**29.18%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(1.71)	(1.67)	(2.47)	(3.02)	(3.64)	(3.87)	(5.10)	(5.43)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(13.63)	(12.23)	(12.44)	(13.04)	(12.44)	(11.37)	(10.99)	(9.56)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(15.34)**	**(13.90)**	**(14.91)**	**(16.06)**	**(16.08)**	**(15.24)**	**(16.10)**	**(14.99)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**18.99**	**26.97**	**30.64**	**33.40**	**36.75**	**40.19**	**41.66**	**44.24**

Table 72: Carbon accounting results for the Private-Harvest management scenario, under an "intermediate" fire frequency and variable risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**0.69%**	**2.74%**	**6.06%**	**10.52%**	**15.94%**	**22.12%**	**28.84%**	**35.88%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.04)	(0.16)	(0.51)	(1.09)	(1.99)	(2.93)	(5.04)	(6.67)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.32)	(1.15)	(2.58)	(4.70)	(6.80)	(8.62)	(10.87)	(11.76)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.36)**	**(1.30)**	**(3.10)**	**(5.79)**	**(8.78)**	**(11.55)**	**(15.91)**	**(18.44)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**33.97**	**39.56**	**42.45**	**43.67**	**44.05**	**43.87**	**41.84**	**40.79**

Table 73: Carbon accounting results for the Private-Harvest management scenario, under an "intermediate" fire frequency and constant risk model (MFI 50 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	50	50	50	50	50	50	50	50	50
Probability of Fire	**-**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**	**9.61%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.56)	(0.55)	(0.81)	(0.99)	(1.20)	(1.27)	(1.68)	(1.79)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(4.49)	(4.03)	(4.10)	(4.29)	(4.10)	(3.74)	(3.62)	(3.15)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(5.05)**	**(4.58)**	**(4.91)**	**(5.29)**	**(5.29)**	**(5.02)**	**(5.30)**	**(4.94)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**29.28**	**36.29**	**40.64**	**44.17**	**47.54**	**50.41**	**52.46**	**54.29**

Table 74: Carbon accounting results for the Private-Harvest management scenario, under a "contemporary" fire frequency and variable risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Weibull								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**0.04%**	**0.17%**	**0.39%**	**0.69%**	**1.08%**	**1.55%**	**2.10%**	**2.74%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.00)	(0.01)	(0.03)	(0.07)	(0.13)	(0.21)	(0.37)	(0.51)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(0.02)	(0.07)	(0.17)	(0.31)	(0.46)	(0.60)	(0.79)	(0.90)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(0.02)**	**(0.08)**	**(0.20)**	**(0.38)**	**(0.59)**	**(0.81)**	**(1.16)**	**(1.41)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**34.31**	**40.78**	**45.35**	**49.08**	**52.24**	**54.61**	**56.59**	**57.82**

Table 75: Carbon accounting results for the Private-Harvest management scenario, under a "contemporary" fire frequency and constant risk model (MFI 200 years). Values (metric tons GHGe) are in terms of GHG emissions, where positive values are net emissions or equivalent carbon lost, and (negative) values are net carbon sequestration or equivalent emissions avoided.

PRIVATE - HARVEST									
	Time (yrs)								
Parameter	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1) Forest Carbon - Stock and Growth									
BASE - Forest Sequestration (GHG / ac)	(229)	(249)	(271)	(295)	(319)	(346)	(373)	(401)	(429)
PRIVATE HARVEST - Forest Sequestration (GHG / ac)	(229)	(195)	(212)	(233)	(255)	(279)	(304)	(331)	(358)
Net Forest Carbon Liability (Difference - GHG / ac)	**-**	**54.78**	**58.74**	**61.91**	**64.54**	**66.98**	**68.77**	**70.42**	**71.29**
2) Forest Carbon - Wood Product LCA									
Non-merchantable Wood Products (Slash)									
Total Slash Removed (GHG / ac)	-	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
% Slash Diverted to Biomass Utalization	-	95%	95%	95%	95%	95%	95%	95%	95%
Field Biomass LCA (% additional)	-	20%	20%	20%	20%	20%	20%	20%	20%
Net Non-merch Diverted to Biomass (GHG / ac)	-	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)	(1.48)
Merchantable Wood Products									
Total Merch Removed (GHG / ac)	-	28.96	28.96	28.96	28.96	28.96	28.96	28.96	28.96
Merch Going to Wood Products(GHG / ac)	-	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)	(17.38)
Wood Products Still in End Use (GHG / ac)	-	(15.20)	(13.50)	(12.13)	(11.00)	(10.06)	(9.26)	(8.58)	(7.98)
Merch Residuals Diverted to Waste (GHG / ac)	-	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)	(11.58)
% Waste Diverted to Biomass Utilization	-	75%	75%	75%	75%	75%	75%	75%	75%
Mill Biomass LCA (% additional)	-	30%	30%	30%	30%	30%	30%	30%	30%
Net Merch Diverted to Biomass LCA (GHG / ac)	-	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)	(2.61)
Waste Remaining after Biomass Utilization (GHG / ac)	-	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)	(2.90)
Mill Waste LCA (% additional)	-	40%	10%	5%	0%	0%	0%	0%	0%
Net Merch Diverted to Waste LCA (GHG / ac)	-	(1.16)	(0.29)	(0.14)	-	-	-	-	-
Net Merch LCA Emissions (GHG / ac)	-	(18.97)	(16.40)	(14.88)	(13.60)	(12.67)	(11.87)	(11.19)	(10.58)
Total Wood Product LCA Benefit (GHG / ac)	**-**	**(20.45)**	**(17.87)**	**(16.36)**	**(15.08)**	**(14.14)**	**(13.35)**	**(12.67)**	**(12.06)**
3) Fire Risk									
Fire Probability Distribution	Constant								
Expected Median Fire Return Interval (Years)	200	200	200	200	200	200	200	200	200
Probability of Fire	**-**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**	**2.48%**
4) Wildfire Emissions									
Direct Emissions									
PRIVATE HARVEST - Direct Emissions (GHG / ac)	55	49	52	52	55	55	54	55	53
BASE - Direct Emissions (GHG / ac)	55	55	57	61	65	67	67	72	71
Net Direct Wildfire Emissions (GHG / ac)	-	(5.86)	(5.71)	(8.47)	(10.35)	(12.47)	(13.26)	(17.49)	(18.60)
Net Direct Wildfire Emissions w/Risk (GHG /ac)	-	(0.15)	(0.14)	(0.21)	(0.26)	(0.31)	(0.33)	(0.43)	(0.46)
Treatment Shadow									
% Change in Fire Size	0%	-85%	-73%	-70%	-68%	-63%	-58%	-52%	-46%
Indirect Emissions									
Treatment Shadow Effect Emissions (GHG / ac)	-	(46.71)	(41.92)	(42.64)	(44.70)	(42.64)	(38.97)	(37.68)	(32.78)
Net Indirect Wildfire Emissions w/Risk (GHG /ac)	-	(1.16)	(1.04)	(1.06)	(1.11)	(1.06)	(0.96)	(0.93)	(0.81)
Total Avoided Wildfire Emissions Benefit (GHG/ac)	**-**	**(1.30)**	**(1.18)**	**(1.27)**	**(1.36)**	**(1.36)**	**(1.29)**	**(1.37)**	**(1.27)**
5) Total Accumulated Benefit or Liability (GHG / ac)	**-**	**33.03**	**39.68**	**44.28**	**48.10**	**51.47**	**54.13**	**56.39**	**57.96**